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Low Reproductive Success of Mallards in a Grassland-Dominated Landscape in The Sandhills of Nebraska

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ABSTRACT -- The Sandhills of Nebraska comprise approximately 5,000,000 ha of native grassland interspersed with numerous groundwater-fed wetlands. A substantial population of the mallard (*Anas platyrhynchos*) nests in this region. Previous investigations of nest survival probability of ducks in the Sandhills have estimated surprisingly low rates of nest survival for a grassland-dominated landscape. These investigations were conducted on public lands and most nest searching took place near wetlands where activity of nest predators might be highest. We predicted that mallards would nest at varying distances from wetlands and that survival probability of a representative sample of duck nests would increase with distance from wetlands. We decoy-trapped and radio-marked 71 female mallards, 32 during the 2005 nesting season and 39 during the 2006 nesting season, and monitored their individual choice of nest habitats, their survival during the nesting season, and survival of their nests. Mallards nested in various habitats, both near and far from wetlands. Nest survival probability ($\hat{S}$ = 0.03, SE = 0.02) was low relative to other studies regardless of distance to wetlands. Survival of females during the nesting season ($\hat{S}$ = 0.84, SE = 0.08), however, was high relative to other studies. This pattern could have resulted from the combination of a diverse community of nest predators, few predators of nesting females, and a population of largely second year females that put little effort into nesting.

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Key words: *Anas platyrhynchos*, mallard, Nebraska, nesting, predation, radio telemetry, Sandhills, survival probability.

The Sandhills of Nebraska comprise the largest continuous expanse of native grassland remaining in North America: an area of approximately 5,000,000 ha (Bleed and Flowerday 1990). The grasslands of the Sandhills are interspersed with more than 394,000 ha of wetlands, including permanent lakes, seasonally-flooded meadows and, less frequently, fens (LaGrange 2005). These wetlands are influenced strongly by groundwater dynamics (Novacek 1989). Most of the region is in private ownership, and the dominant land-use practice is cattle (*Bos taurus*) grazing for beef production (Novacek 1989).

Substantial numbers of the mallard (*Anas platyrhynchos*) nest in the Sandhills. Nebraska Game and Parks Commission (NGPC) biologists have counted up to 250,000 breeding ducks in the region during annual spring surveys conducted from the air (Nebraska Game and Parks Commission, unpublished data). The mallard was the most common species in this survey composing 35% of the total pair count on average. Nonetheless, the few previous investigations of nest survival of upland-nesting ducks (mallard, gadwall (*Anas strepera*), and blue-winged teal (*Anas discors*) in the Sandhills have indicated that nest survival in this region is low (Glup 1987). These observations conflict with the higher nest survival observed in landscapes that are dominated by grassland in the Prairie Pothole Region (PPR; Greenwood et al. 1995, Reynolds et al. 2001, Stephens et al. 2005) where researchers have concluded that grassland-dominated landscapes are associated with lower rates of nest predation (Sargeant et al. 1993). Much of the research on nest survival of ducks in the Sandhills, however, was conducted on public lands (e. g., National Wildlife Refuges) and nest searching largely was limited to areas near wetlands. We suspected that these samples might not have been representative of the fates of nests located in the majority of privately-owned grassland habitat in the Sandhills. Nests located near wetlands might have been in areas where predator activity was highest and nest survival was lowest given that increased foraging activity near wetlands by nest predators has been observed in the PPR (Phillips et al. 2003).

We predicted that mallards would nest at various distances from wetlands and that survival probability of mallard nests located in grassland habitats in the Sandhills would increase with distance from wetlands. We initiated an investigation of the nesting ecology of mallards on private land in the Sandhills to evaluate the validity of this prediction. We marked female mallards with radio-transmitters prior to breeding and observed them through the nesting season so that the resulting nest sample would be representative of the range of selected habitats. This design also allowed us to estimate other vital rate parameters such as female survival during the breeding season, hen success,

clutch size, and the proportion of nests initiated in different habitat types. To our knowledge, this study was the first effort to quantify these parameters for breeding ducks in the Sandhills.

METHODS

We investigated the reproductive success of mallards on a single study area in the Sandhills during April to July 2005 and 2006. The study area was located approximately 24 km south of Bassett, Nebraska (42° 20' N, 99° 29' W) and encompassed 26,347 ha (Fig. 1). Land-cover of the study area derived from a classification of 20-m SPOT imagery was composed of 69% native grassland, 14% hayland, 11% wetlands, 1% cropland, and 5% other classes (e.g., bare soil; Ducks Unlimited, unpublished data).

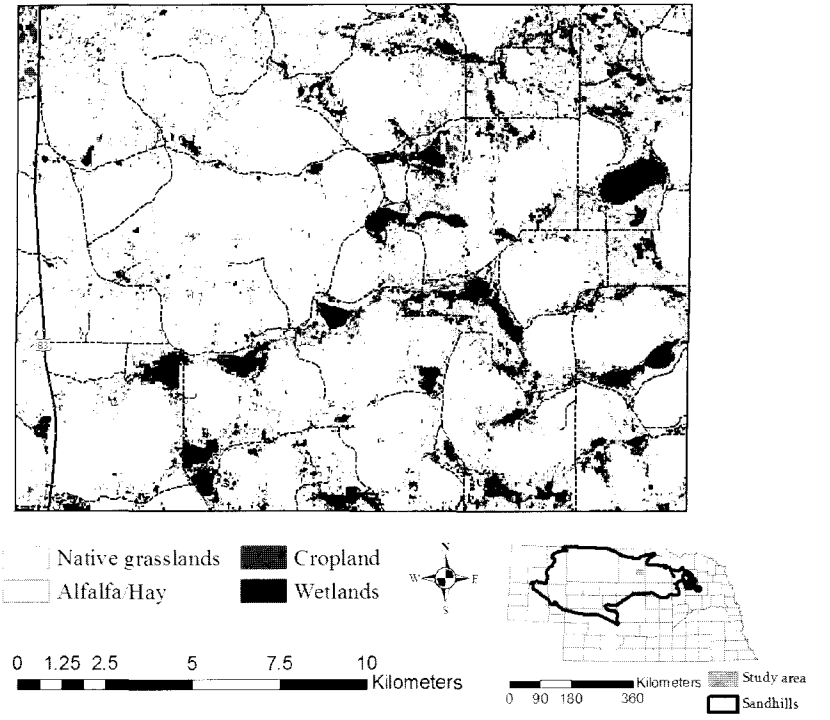

Figure 1. Location, extent, and dominant land cover of the study area where we studied mallard reproduction in the Sandhills of Nebraska during 2005 and 2006.

Our study area was typical of the eastern Sandhills in terms of climate, land-use, and plant community. Annual precipitation averaged 51 cm to 58 cm. Average summer temperature ranged from 19.4° C to 23.9° C. Dominant land-use practices were cattle grazing and forage cultivation. A detailed description of the native plant community of the Sandhills is given by Bleed and Flowerday (1990).

To capture females prior to nesting, we used decoy traps placed on wetlands where we observed mallard pairs behaving territorially (Sharp and Lokemoen 1987). When we captured a female we recorded her mass (± 5 g) and structural size (head length, tarsus length, and keel length; ± 0.1 mm) and fitted her with a United States Geological Survey (USGS) aluminum leg band. We attached a 5-gram radio transmitter (Model A4370; Advanced Telemetry Systems, Isanti, Minnesota) between her wings on the dorsal side and released her on the same wetland where she was captured (Pietz et al. 1995). Captured males were fitted with a USGS aluminum leg band and released. When we captured both members of a pair, we released them together to minimize disruption of pair bonds. The capture, handling, and marking procedures were approved by the Institutional Animal Care and Use Committee (IACUC) of the University of Nebraska (IACUC protocol #05-02-008).

We located radio-marked females 1 to 2 times daily by using truck-mounted and hand-held radio antennas and receivers. Females that left the study area were censored from the sample at the time of their last positive location. If a radio-marked female was observed in an upland location for two consecutive days, then we assumed she had initiated a nest. We attempted to locate the nest by triangulating on the location of the marked female and returning when she was absent. When we were unable to locate the nest by this method we waited 5 to 7 days (to minimize abandonment) and located the nest by flushing the female.

We recorded habitat type, number of eggs, stage of incubation (Weller 1956), and a measurement of horizontal vegetation density (Robel et al. 1970) at each nest, and we recorded the Universal Transverse Mercator (UTM) coordinates of the nest by using a handheld Global Positioning Systems (GPS) receiver. We revisited nests every 1 to 3 days until they were abandoned, destroyed, or the eggs hatched. We estimated the distance from each nest to the nearest wetland (±1 m) by using a landcover classification developed from satellite imagery of the study area taken in 2005. We also periodically located females during the brood-rearing period and attempted to count their ducklings. All marked females that remained on the study area were monitored for the duration of the study.

Predation rate on nests was very high in 2005. We deployed baited track plates (Kuehl and Clark 2002) in 2006 in an attempt to derive a preliminary assessment of the composition of the predator community on the study area. Track plates (2.5 m^2) composed of a sand and mineral oil mixture, scented plaster wafer, and plaster cast faux eggs were dispersed systematically throughout the study site. We placed track plates every 30 m radiating out from an active nest in

the four cardinal directions in an attempt to identify potential predators at marked nests. Track plates were set in this same pattern in locations without active marked nests to determine potential predators searching the remaining habitat types.

We observed that many of the females captured in 2006 had feather characteristics consistent with those of Second Year (SY; i.e., approximately one-year-old) individuals. We removed greater secondary coverts from one wing of these females and compared the feathers to those in Carney (1992) to estimate the proportion of SY and After-Second-Year (ASY) birds in the 2006 sample.

We used the nest survival module in Program MARK 4.3 (White and Burnham 1999, Dinsmore et al. 2002) to estimate Daily Nest Survival (DNS) and Daily Survival Rate (DSR) of radio-marked females. We developed models of nest survival by using year, calendar date, horizontal vegetation density (ROBEL), and distance to water (DW) as predictors. Models of female survival included year and mass at capture as predictors. We evaluated relative support for competing models by using AICc differences and AICc weights (Burnham and Anderson 1998).

We estimated clutch size and number of nesting attempts per female by using Program R 2.3.1 (Ihaka and Gentleman 1996, R Development Core Team 2006). We estimated hen success as the product of nest survival probability and the number of nesting attempts per female, and we estimated the sampling variance of hen success by the delta method (Seber 1982). We estimated the proportion of nests in three habitat classes (grassland, hayland, and cropland) by assuming that these proportions followed a multinomial distribution. We also calculated survival probability of radio-marked females over a 22-week breeding season (i.e., DSR^{154}) to facilitate comparisons with other studies (Brasher et al. 2006).

RESULTS

We captured and radio-marked 32 female mallards in 2005, four of which were never detected again after capture and marking. We detected nests for 20 of the remaining 28 (71%). We radio-marked 39 female mallards in 2006, three of which were never detected again after capture and marking. We detected nests for 18 of the remaining 36 (50%). In total, we detected 28 nest initiations for 20 females in 2005 and 18 nest initiations for 36 females in 2006. Only one radio-marked female produced a brood in 2005. In 2006, there were zero broods produced. Therefore, we did not attempt to monitor or estimate brood survival.

Our best-approximating model indicated that DNS varied between years. Nonetheless, there was considerable model selection uncertainty, and the null model was a more parsimonious approximation (Table 1). Estimated, logit-scale slope coefficients from competing models for date (0.01; SE = 0.01), ROBEL (-0.04; SE = 0.12), and DW (0.001; SE = 0.01) were indistinguishable from zero. Estimated nest survival probability (i.e., DNS36; Klett et al. 1986) from the null model was 0.03

Table 1. Models of daily survival probability of mallard nests in the Sandhills of Nebraska during 2005 and 2006.

Model	Delta AICc	AICc Weight	Number of Parameters
Year	0.000	0.330	2
Null	0.276	0.287	1
Date	2.037	0.119	2
ROBEL[1]	2.218	0.109	2
DW[2]	2.290	0.105	2
Year*Date	3.788	0.050	4

[1]ROBEL is a measure of horizontal vegetation density.

[2]DW is the estimated distance from the nest to water.

(SE = 0.02). Estimated year-specific nest survival probability was 0.01 (SE = 0.01) in 2005 and 0.06 (SE = 0.05) in 2006.

We also estimated number of nesting attempts per nesting female, clutch size, female success, and the proportion of nests located in each habitat class. Average number of nesting attempts per nesting female during 2005 and 2006 was 1.31 (SE = 0.21); year-specific number of nesting attempts was 1.37 (SE = 0.27) in 2005 and 1.23 (SE = 0.32) in 2006. Estimated clutch size of radio marked mallards averaged 8.70 (SD = 1.84) in 2005 and 7.27 (SD = 1.77) in 2006. Estimated female success for both years combined was 0.04 (SE = 0.04) and was 0.01 (SE = 0.03) in 2005 and 0.07 (SE = 0.10) in 2006. Most nests were located in grassland habitat in both years (Fig. 2).

Daily survival rate of radio-marked females during the 2005 and 2006 nesting seasons was best described by a constant model, but there was some support for a positive relationship between DSR and mass at capture and variation between years (Table 2). Year-specific estimates were terms indistinguishable from each other. The estimated coefficient for mass (0.01; SE = 0.01) was not different from zero. Thus, the null model was most parsimonious of these competing models.

Daily probability of survival for a female mallard captured and radio marked on our study area was 0.999 (SE = 0.006). Estimated 22-week survival probability of radio-marked females on our study area was 0.84 (SE = 0.08). The age distribution of marked females in 2006 was highly skewed. Twenty of 23 (87%) of mallard females aged in 2006 were SY birds.

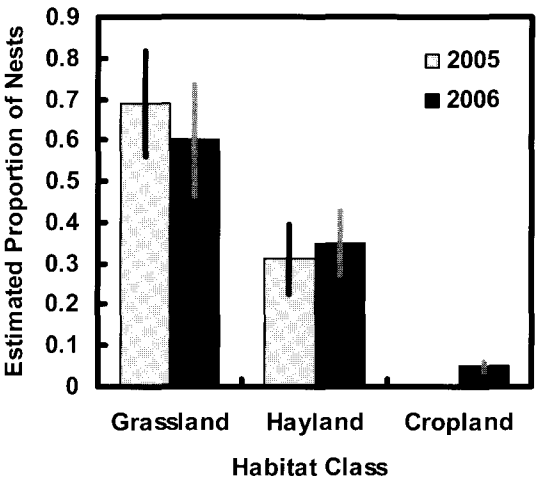

Figure 2. Estimated proportion of mallard nests (±SE) in major habitat types on the Sandhills study site during 2005 and 2006.

We detected at least eight species of potential nest predators with the track plates we deployed in 2006: coyote (*Canis latrans*), striped skunk (*Mephitis mephitis*), raccoon (*Procyon lotor*), ground squirrel (*Spermophilus* spp.), Virginia opossum (*Didelphis virginiana*), American badger (*Taxidea taxus*), long-tailed weasel (*Mustela frenata*), and weasel (*Mustela* spp.). In addition to the detections of mammals, we also detected raptors and snakes at track stations.

DISCUSSION

We accrued no support for our hypothesis that nest survival would increase with distance to wetlands. We also observed no relationship between nest survival and ROBEL although most nests were located in grassland habitat with an average lateral density of 3.18 dm (SD = 1.50 dm) and on average were located 376 m (SD = 396 m) from water. Thus, we were doubtful that a strong relationship existed between nest survival and any of these variables.

Survival of nests was surprisingly low on our study area during 2005 and 2006. We had expected nest survival probability in a large area of intact grassland like our study area to be higher. The average nest survival probability that we observed over two-years was lower than average nest survival estimates from many intensively-cultivated sites in the PPR (Greenwood et al. 1995, Reynolds et al. 2001, Stephens et al. 2005). Most failed nests were destroyed by predators, and we

Table 2. Models of daily survival probability of female mallards in the Sandhills of Nebraska during 2005 and 2006.

Model	Delta AICc	AICc Weight	Number of Parameters
Null	0.000	0.357	1
Mass	0.120	0.335	2
Year	0.289	0.308	2

observed evidence in 2006 from track plates that the predator community on the study area was as diverse as any in the PPR (Sargeant et al. 1993). Thus, our observations provided little support for the idea that predator communities were less diverse (Sovada et al. 1995) on our grassland-dominated study area.

Most other parameters related to nesting were comparable to estimates of the same parameters from the PPR. Average clutch size of mallards on our study area was similar to that reported in Bellrose (1976) in 2005 and might have been one egg lower in 2006. Similarly, number of nests per nesting female was similar to the unadjusted estimate (1.41 nests/female) reported by McPhereson et al. (2003). These estimates indicated to us that clutch size or renesting propensity probably were not limiting production on this study area. We concluded that success of nesting females was extremely low on our study area largely as a result of low nest survival (high nest predation).

Estimated 22-week survival probability of radio-marked females on our study area ($\hat{S}$ = 0.84, SE = 0.08) was generally high relative to that observed by other researchers. Cowardin et al. (1985) reported survival of female mallards of 0.81 (SE = not reported) but suspected that their estimate was biased high because of transmitter loss (right-censoring) related to predation. A lower estimate from the prairie parklands of Canada ($\hat{S}$ = 0.60, SE = not reported) was reported by Blohm et al. (1987). Also in the Canadian prairie-parklands, Brasher et al. (2006) estimated breeding season survival of 0.78 (SE = 0.025).

Breeding season survival of females commonly is thought to be negatively related to nesting effort because most mortality of female mallards during the breeding season occurs on nests (Sargeant and Raveling 1992, DeVries et al. 2003). We observed nesting effort comparable to that of prairie mallards on the part of females for which we detected nests. Nevertheless, we did not detect any nests for many radio-marked females.

We found nests for only 71% of females in 2005 and 50% of females in 2006. This is an extremely low proportion of nesting birds in a sample of mallards marked with prong-and-suture mount radio transmitters. The low proportion of nesting birds in our sample could be an artifact of our methods. For example, transmitter

effect might have caused females to put less effort into nesting or we might have failed to detect a substantial proportion of nests because many nests were destroyed early in incubation. Alternatively, the proportion of nesting females on our study area might have been low for an unknown ecological reason.

Nevertheless, we doubt that a transmitter effect produced the results that we observed. There is little evidence to support the idea of a strong relative effect of prong-and-suture mount transmitters on the probability of initiating a nest although females marked with prong-and-suture mount radios initiate fewer total nests and spend fewer days laying and incubating eggs (Paquette et al. 1997). During a study of mallard breeding ecology in North Dakota that was concurrent with our study in the Sandhills, researchers detected nests for 85% of radio-marked female mallards (Mark Sherfy, United States Geological Survey, Northern Prairie Wildlife Research Center, unpublished data). These mallards were marked with transmitters identical to the transmitters we used to mark mallards in the Sandhills and were tracked by using similar protocols. Furthermore, we tracked all of the marked females in the sample daily, and although it is almost certain that we missed some nests (see McPherson et al. 2003), it is doubtful that we missed enough nests to cause such great disparities between our study and other studies that used nearly identical methods (Paquette et al. 1997, M. Sherfy, United States Geological Survey, unpublished data). Thus, we think that a low proportion of females on our study area nested.

We suspect that the relatively low proportion of nesting females and relatively high survival probability that we observed was related to the age of the birds we marked. Our sample consisted of 87% SY females in 2006. In contrast, Devries et al. (2003) reported about 48% SY females in their sample collected over 19 site-years in the Canadian prairie parklands; the highest proportion of SY females observed in an individual site-year was about 60%. Second Year female mallards tend to invest less energy in nesting and brood-rearing (Reynolds et al. 1995, Dufour and Clark 2002). Thus, a population of SY mallards breeding in an environment with low potential for reproductive success might exhibit reduced breeding effort and higher survival. Further, the predator community on our study area might have favored higher survival of breeding females. Although we detected a diverse group of nest predators on our study area we did not detect red fox (*Vulpes vulpes*): possibly the major predator of nesting female ducks in the PPR (Sargeant and Raveling 1992, Sovada et al. 1995).

Mallard production on our study area was very low during 2005 and 2006. However, additional information would be required to make inference to the breeding mallard population in the Sandhills. We might have selected a site where reproductive success is consistently low, or we might have observed two very poor years for reproductive success. Reproductive success of the mallard is quite variable in space and time across its breeding range (Johnson et al. 1992, Hoekman et al. 2002) and it is probably variable in the Sandhills as well.

Nonetheless, our study raised some interesting questions about duck production in the Sandhills. For example, what is the level of spatial and temporal variation in predator communities and reproductive success of the mallard across the Sandhills region? Is the mallard population nesting in the Sandhills composed primarily of females in their first breeding season? Are predator communities consistently more diverse in the grassland-dominated landscape of the Sandhills than similar landscapes in the PPR? These questions could be answered with data collected during multiple (at least two) breeding seasons from a probability sample of sites across the Sandhills. The results of such an effort would be useful to waterfowl managers given the size of the population of mallards counted during the breeding season and the potential threats to groundwater resources and wetland habitat in this region.

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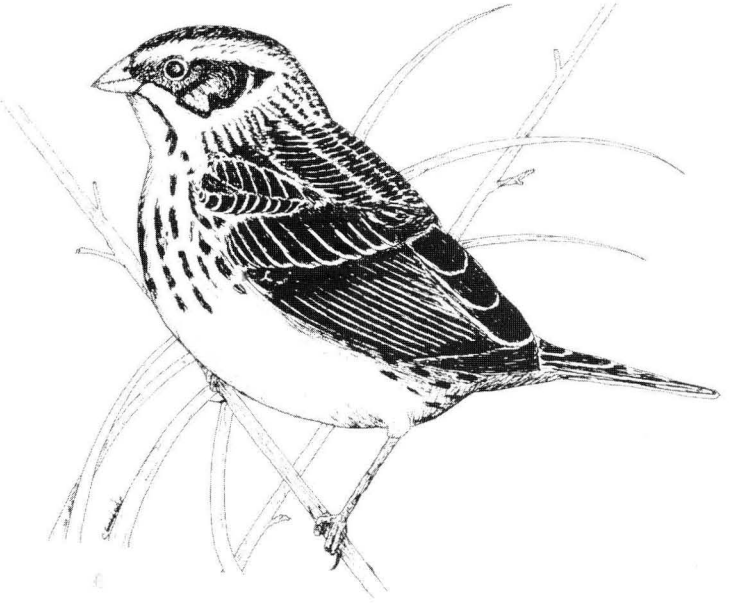

Use of Passive Integrated Transponders in Hatchling Texas Horned Lizards

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ABSTRACT -- The Texas horned lizard (*Phrynosoma cornutum*) is a Texas state-threatened species and acquisition of data related to the species' ecology is essential. To accomplish this task individual animals need to be marked. Many marking techniques are available for lizards, however the majority of techniques have been tested on adults only. Studies involving hatchling and juvenile horned lizards are scarce due to problems associated with marking and relocating individuals in these age classes. I demonstrated that injection of passive integrated transponders (PIT's) can safely be used as a marking method in young Texas horned lizards. Thirty-two captive bred hatchling lizards were used. Hatchlings were allowed to grow to 20 mm snout-vent length (SVL) before PIT's were inserted into 16 hatchlings while the other 16 hatchlings were used as control animals. Hatchlings were measured and weighed weekly for 14 weeks and blood samples obtained weekly for 3 weeks to assess if PIT's affected lizard growth and health. No differences were noted in treatment effects for SVL ($F_{1,450} = 0.85$, $P = 0.37$), weight ($F_{1,450} = 1.60$, $P = 0.22$), or white blood cell and differential counts ($F_{1,30} < 1.47$, $P > 0.23$). However, an interaction between treatment and week occurred ($F_{14,450} = 1.79$, $P = 0.04$) for SVL. Texas horned lizard hatchlings that were PIT-tagged were larger in SVL during weeks 3, 7 to 10, and 12 than control lizards. No differences in SVL were noted between treatment groups during the remaining weeks. A duration effect was noted for both SVL ($F_{14,450} = 7654.0$, $P = 0.0001$) and mass ($F_{14,450} = 1595.1$, $P = 0.0001$). Snout-vent length for both PIT-tagged and control lizards increased weekly until week 12 when growth rate began to slow down. Mass gain for both groups of lizards was similar, with weekly spurts occurring except between weeks 0 and 1, 7 and 8, 12 and 13, and 13 and 14. Passive integrated transponders did not interfere with the growth or health of young Texas horned lizards; therefore, they can be safely used as a marking tool.

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Key words: hatchling, marking device, passive integrated transponder, *Phrynosoma cornutum*, reptile, Texas horned lizard.

The Texas horned lizard (*Phrynosoma cornutum*) was once widespread and abundant throughout Texas (Donaldson et al. 1994), however its population has experienced a dramatic decline (Henke 2003). Because of this, the Texas horned lizard is listed as a threatened species by the state of Texas (Texas Parks and Wildlife Code 1987) and as a Species of Concern by the United States Fish and Wildlife Service, federal category C2 (http://www.tpwd.state.tx.us/huntwild/wild/species/thlizard/).

Knowledge of individual movements is essential to understand a species' ecology, however animals must be individually marked to obtain such information. Marking methods for horned lizards have included hot branding (Clark 1971), toe clipping (Ferner 1979, Henke and Montemayor 1998), body tags (Fisher and Muth 1989), fluorescent powder (Stark and Fox 2000), radioactive markers (O'Brien et al. 1965), and transponders (Camper and Dixon 1988, Henke and Montemayor 1998). Problems associated with each marking method have been espoused (Ferner 1979). For example, hot branding can cause abnormal behavior and greater mortality due to infection (Nietfeld et al. 1994), toe clipping is not favored by many Institutional Animal Care and Use committees because it is a mutilation technique (S. E. Henke, Texas A&M University-Kingsville, personal observation), body tags can get caught in vegetation and debris entangling the animal (Nietfeld et al. 1994), radioactive markers can harm or kill animals carrying them (Nietfeld et al. 1994), and fluorescent powder and dyes potentially can make lizards visible to predators thus increasing their mortality, however to my knowledge this has not been quantified for lizards. Passive integrated transponders (PITs) have been used safely and successfully in adult Texas horned lizards (Camper and Dixon 1988), but have yet to be evaluated for safe use in hatchling and juvenile horned lizards. I evaluate the use of PIT's in hatchling (i.e., 3 to 14 week old) Texas horned lizards.

METHODS

Five adult Texas horned lizards (2M:3F) were obtained from Texas Parks and Wildlife Department biologists, who confiscated them from individuals who illegally collected them in Texas. Because the collection location was unknown, lizards were not released. Instead the adults were allowed to be maintained in captivity for educational purposes via permit No. SPR0890-274, which is held by the Horned Lizard Conservation Society.

Adults were held in a 227-liter aquarium equipped with a 13-cm layer of sandy soil, heat lamp, and refugia. They were given food (i.e., harvester ants (*Pogonomrymex* sp.) and crickets (Family Gryllidae)) and water *ad libitum*.

From these adults, two clutches of hatchlings were born in captivity. Clutch 1, which consisted of 14 hatchlings (7M:7F), emerged on 13 July 2001, while Clutch 2, which consisted of 18 hatchlings (8M:10F), emerged on 17 July 2001. Upon emergence, hatchlings were measured for snout-vent length (SVL), weighed, and sexed. Sex determination was verified after they were greater than 1 year old. Sex determination of individuals at hatching was accurate. Because hatchlings at emergence measured 10 to 11 mm SVL and weighed less than 1 gram, they were allowed three weeks growth to be at least 20 mm SVL. This growth time was needed because many hatchlings at emergence were smaller than the length of a PIT.

Hatchlings were divided into two groups. Group 1 received a PIT and group 2 was the control group. Group 1 consisted of seven hatchlings from clutch 1 (4M:3F) and nine hatchlings from clutch 2 (5M:4F). Group 2 consisted of seven hatchlings from clutch 1 (3M:4F) and nine hatchlings from clutch 2 (3M:6F). All hatchlings were marked individually by toe-clipping (Cagle 1939) and in addition, members of group 1 received a PIT (AVID Microchip ID Systems, Mandeville, Louisiana). Passive integrated transponders, which measured 11 x 2 mm and weighed 0.08 g, were injected intraperitoneally in the abdominal region via a 16-gauge needle. Hatchlings were maintained in eight 76-liter aquaria, which were set up as previously described. Four hatchlings, two from groups 1 and 2, respectively, were maintained per aquarium. Food and water were provided *ad libitum*. Hatchlings were monitored weekly to assess their health for three weeks after implanted with a PIT. About 0.2 mL of blood were collected in heparinized syringes via ventral tail caudal vein puncture (Powell and Knesel 1992). White blood cells (WBC) were counted by using Isoton II solution and lytic reagent in a Z1 particle counter (Beckman-Coulter, Inc., Fullerton, California). Thin blood smears were prepared at the time of collection and stained with a Wrights-Giemsa stain within 24 hr. Differential WBC counts were conducted by counting 200 leukocytes at 1,000X magnification. Hatchlings also were weighed to the nearest 0.1 g and measured (SVL) weekly until they entered hibernation. Individuals again were monitored at time of spring emergence. In addition, hatchlings were observed throughout the study to subjectively determine if PIT's adversely affected movements or caused obvious abnormal behaviors.

I used a repeated measures design with treatment (PIT-tagged and control), sex (male and female), and week (0 = initial through 14) as main effects and hatchlings (N = 32) as replications. The distribution of residual errors was tested to verify normality with the Shapiro-Wilk test (PROC UNIVARIATE procedure; SAS 1989). Homogeneity of variances among treatments was evaluated with Bartlett's test (Steel and Torrie 1980). A general linear analysis of variance (PROC GLM; SAS 1989) was used to test the main and interactive effects on the growth and health of the hatchlings. Because

the effect of sex and its corresponding interactive effects were not significant ($F_{1,11} < 1.48$; $P > 0.44$), hatchlings were pooled irrespective of sex and re-analyzed with the main and interactive effects of treatment and weeks. Multiple comparisons were made by using Tukey's studentized range (HSD) test when a significant F-test was noted (Cochran and Cox 1957). Single variants of the interaction were analyzed separately within each grouping of the other main effects when a significant interaction was noted. Statistical significance was inferred at $P < 0.05$.

RESULTS and DISCUSSION

Passive integrated transponders did not affect the growth (Table 1) or health (Table 2) of hatchlings. No mortalities or abnormal behaviors and movements were noted for any individual. White blood cell and differential counts were similar ($F_{1,30} < 1.47$, $P > 0.23$) between PIT-tagged and control lizards (Table 2). Also, differences were not observed ($F_{2,60} < 0.78$, $P > 0.46$) in week or interactive effects for blood counts. No differences were noted in treatment effects for SVL ($F_{1,450} = 0.85$, $P = 0.37$), mass ($F_{1,450} = 1.60$, $P = 0.22$), or in the interactive effect for mass ($F_{14,450} = 1.26$, $P = 0.23$). However, an interaction between treatment and week occurred ($F_{14,450} = 1.79$, $P = 0.04$) for SVL. Hatchlings that were PIT-tagged were larger in SVL during weeks 3, 7, 8, 9, 10, and 12 than control hatchlings (Table 1). No differences in SVL were noted between treatment groups during the remaining weeks. A duration effect was noted for both SVL ($F_{14,450} = 7654.0$, $P = 0.0001$) and mass ($F_{14,450} = 1595.1$, $P = 0.0001$). Snout-vent length for both PIT-tagged and control hatchlings increased weekly until week 12 when growth rate began to slow down (Table 1). Mass gain for both treatment groups was similar (Table 1), with weekly gains occurring except between weeks 0 and 1, 7 and 8, 12 and 13, and 13 and 14 (Table 1). Average growth rate for hatchlings was 0.518 ± 0.01 mm/d during the first 11 weeks; whereas average growth rate declined to 0.171 ± 0.01 mm/d during the 3 weeks prior to hibernation. Hibernation occurred between 16 November and 1 December 2001 and re-emergence after hibernation occurred between 15 and 21 March 2002. Average hatchling growth during hibernation was 0.011 ± 0.001 mm/d. Mass loss after re-emergence was similar ($F_{1,30} = 1.3$, $P = 0.27$) between hatchlings that received a PIT (5.6 ± 0.2 g; $\bar{x} \pm SE$) and the control hatchlings (5.1 ± 0.3 g).

Passive integrated transponders can be safely used to individually mark Texas horned lizards that are at least 20 mm SVL. Transponders did not cause mortality, affect health, obstruct movements, or affect the growth of the hatchlings. Mean growth of hatchlings with and without PIT's was similar to that reported for juvenile Texas horned lizards (Henke and Montemayor 1997). In addition, PIT's did not appear to alter hatchling behavior such as feeding, digging, and basking.

Table 1. Weekly growth of PIT-tagged (treatment; N = 16) and non-tagged (control; N = 16) hatchling Texas horned lizards maintained in captivity from July 2001 to March 2002.

	Snout vent length (mm)				Mass (g)			
	Control		Treatment		Control		Treatment	
Weeks	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
0	21.3 Aa[1,2]	0.2	21.4 Aa	0.2	1.6 Aa	0.1	1.8 Aa	0.1
1	25.4 Ab	0.2	25.2 Ab	0.2	2.4 Aa	0.2	2.4 Aa	0.1
2	29.4 Ac	0.3	29.2 Ac	0.3	4.9 Ab	0.2	4.4 Ab	0.2
3	33.1 Ad	0.4	33.8 Bd	0.2	7.4 Ac	0.2	7.4 Ac	0.2
4	36.6 Ae	0.4	37.5 Ae	0.2	10.6 Ad	0.2	10.4 Ad	0.2
5	40.2 Af	0.4	40.9 Af	0.3	13.8 Ae	0.3	13.7 Ae	0.2
6	43.8 Ag	0.4	44.6 Ag	0.3	17.4 Af	0.3	17.0 Af	0.3
7	47.2 Ah	0.4	48.4 Bh	0.2	20.8 Ag	0.3	21.5 Ag	0.4
8	50.7 Ai	0.4	51.8 Bi	0.2	21.9 Ag	0.3	22.8 Ag	0.4
9	54.0 Aj	0.2	55.2 Bj	0.2	23.9 Ah	0.3	24.5 Ah	0.4
10	57.8 Ak	0.2	58.4 Bk	0.2	26.1 Ai	0.3	25.8 Ai	0.3
11	61.2 Al	0.3	61.3 Al	0.2	27.9 Aj	0.4	27.8 Aj	0.3
12	63.1 Am	0.3	63.7 Bm	0.2	29.5 Ak	0.5	30.1 Ak	0.3
13	64.0 Amn	0.3	64.5 Amn	0.2	30.2 Akl	0.5	31.4 Akl	0.3
14	64.6 An	0.3	65.1 An	0.2	30.4 Al	0.7	32.2 Al	0.3
RE[3]	66.1 Ao	0.4	66.2 Ao	0.1	25.3 A[4]	0.7	26.6 A	0.5

[1]Means with the same upper case letter are not different ($P > 0.05$) between treatments.
[2]Means with the same lower case letter are not different ($P > 0.05$) between weeks within the same treatment.
[3]RI = Re-emergence after hibernation occurred between 15 to 21 March 2002.
[4]Mass loss after re-emergence was not analyzed within weekly growth.

Table 2. Weekly white blood cell (WBC) and differential counts of PIT-tagged (treatment) and non-tagged (control) hatchling Texas horned lizards maintained in captivity from July 2001 to March 2002.

	Control (N=16)						Treatment (N=16)					
	Week 1		Week 2		Week 3		Week 1		Week 2		Week 3	
Blood	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
WBC ($x10^9$/l)	27.5	10.3	29.3	9.7	29.9	6.7	33.4	11.7	29.4	6.8	31.9	2.8
Lymphocyte (%)	25.3	7.8	28.2	8.3	24.4	6.1	26.2	5.7	28.5	3.3	29.3	1.6
Heterophils (%)	62.2	12.2	58.1	11.7	54.4	5.8	64.5	4.7	61.3	2.8	58.1	5.4
Eosinophils (%)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.7	0.2	1.0	0.3
Basophils (%)	1.0	0.3	0.5	0.1	1.8	0.2	0.0	0.0	0.5	0.1	0.5	0.1
Monocytes (%)	11.5	1.2	13.2	1.7	19.4	2.5	9.3	2.0	8.0	0.3	11.1	2.1

Passive integrated transponders during my study did not fail. Camper and Dixon (1988) reported a 1% failure of PIT's implanted in reptiles and amphibians. My study can be used to satisfy animal welfare organizations (i.e., Institutional Animal Care and Use Committees) as to the safety of PIT's for use in hatchling and juvenile lizards.

Long-term population and ecological studies are needed in field herpetology, however herpetologists might be reluctant to use permanent marking techniques until such techniques are shown to be successful. I illustrated that a permanent marking technique can be used for rare and conservation-sensitive species without fear of harming individuals in a population. Permanently marking Texas horned lizards has allowed us to gather information such as dispersal from natal areas, movements, longevity, and potential causes of mortality. By conducting repeated searches during several years, we have been able to map Texas horned lizard locations through time, calculate survival rates, and growth rates (Henke and Montemayor 1997). Also, I have surmised Texas horned lizard mortality from PIT's found inside domestic cat scats, owl pellets, and raptor casts. Such information could be collected via radio telemetry, however, telemetry studies can be expensive and transmitters would require replacement for long-term studies. If budget is a concern and researchers are available, conducting searches for permanently marked Texas horned lizards can yield valuable data (Fair and Henke 1997, Henke and Montemayor 1998).

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Influence of Temperature and Discharge on Reproductive Timing of Common Carp in a Northern Great Plains River

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ABSTRACT -- Reproductive timing of common carp (*Cyprinus carpio*) was examined in the Red River of the North and compared with environmental factors that might have triggered spawning during 1999 and 2000. We estimated spawn dates for individual common carp larvae collected in the drift by back-calculating from date of capture and by accounting for developmental stage at capture and water temperature during the period of egg incubation. Reproductive timing was compared with discharge and water temperature to determine which of these likely might be a synchronizing cue for spawning of common carp in the Red River basin. In both years of the study, water temperature regimes were similar in comparison with time of year; however, discharge hydrographs differed substantially, which provided an opportunity to test our hypothesis that within a window of suitable temperature (and photoperiod), spawning in common carp is triggered by an increase or peak in discharge. The discharge hydrograph during 1999 was typical for the Red River, with peaks in April from snowmelt and precipitation. In atypical 2000 no early spring peak occurred due to a lack of snow cover and spring precipitation, but heavy precipitation produced a peak in discharge much later than normal during the third week of June throughout most of the study area. In both years successful common carp spawning occurred after the first peak in discharge following the attainment of a minimum spawning temperature. These results supported our hypothesis suggesting that a discharge related environmental factor might act as the synchronizing cue for spawning in common carp in some lotic habitats.

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Key words: common carp, *Cyprinus carpio*, environmental cues, river discharge, spawning.

Environmental cues that signal the availability of suitable spawning conditions are crucial to the timing of successful reproduction (Munro et al. 1990). A number of studies have attempted to discern the relative influence of environmental cues on reproductive cycles in fish (De Vlaming 1972, Stacey 1979, Davies et al. 1986). These generally have concluded that photoperiod and water temperature stimulate reproductive development and spawning; however, photoperiod and temperature are usually correlated in a natural ecosystem and their relative influence cannot be easily determined. In addition to its effect on gonadal development, the attainment of a minimum water temperature in the spring also triggers spawning behavior and the release of gametes for many fish species. For example, rising water temperature has been shown to stimulate walleye (*Sander vitreus*) and sauger (*Sander canadensis*) spawning (Koenst and Smith 1976).

In lotic systems, discharge might act as a synchronizing cue to initiate spawning. Discharge is often highly variable and is possibly the most critical abiotic factor structuring lotic aquatic communities (Bain 1985, Schlosser 1985, Harvey 1987). For many fish species, flooding can be essential because it provides complex habitat for reproduction and an increase in available nutrients for young. Many fish spawn at a rise or peak in water level and discharge, giving offspring floodplain resources and the advantage of predator avoidance (Welcomme 1979, Junk et al. 1989, Bayley 1995). In northern climates, floodplain waters might also warm more quickly, which speeds development of offspring (Bayley 1995).

Studies of common carp (*Cyprinus carpio*) and some of their Asian relatives have demonstrated that these species display synchronization in their reproductive timing that is not associated solely with water temperature (Schrank et al. 2001, Phelps 2006). Observational studies suggest that common carp have a reproductive cycle in lotic systems that is influenced highly by flow regime (Swee and McCrimmon 1966, June 1977). Common carp is classified as a phytophil, which requires vegetation as spawning substrate (Balon 1975). High turbidity and shifting sediments in some rivers might prevent the growth of aquatic plants leaving only the floodplain with inundated terrestrial vegetation to provide spawning habitat for common carp and other phytophils.

The purpose of our study was to test the hypothesis that increasing discharge acts as a synchronizing cue to stimulate spawning behavior of common carp when photoperiod and water temperature are within a suitable range. Our specific objectives were to: 1) estimate spawn date for common carp by using larval carp captured in the drift and 2) compare spawn date with existing water temperatures and discharge to determine which was most likely the synchronizing cue triggering spawning.

STUDY AREA

The Red River of the North is formed at the confluence of the Otter Tail and Bois de Sioux rivers near Wahpeton, North Dakota, and flows northward into Lake Winnipeg (Fig. 1). The Red River has a drainage area of 104,202 km^2 (Harkness et. al. 2000). It lies in the bed of Pleistocene Lake Agassiz and has a wide, flat

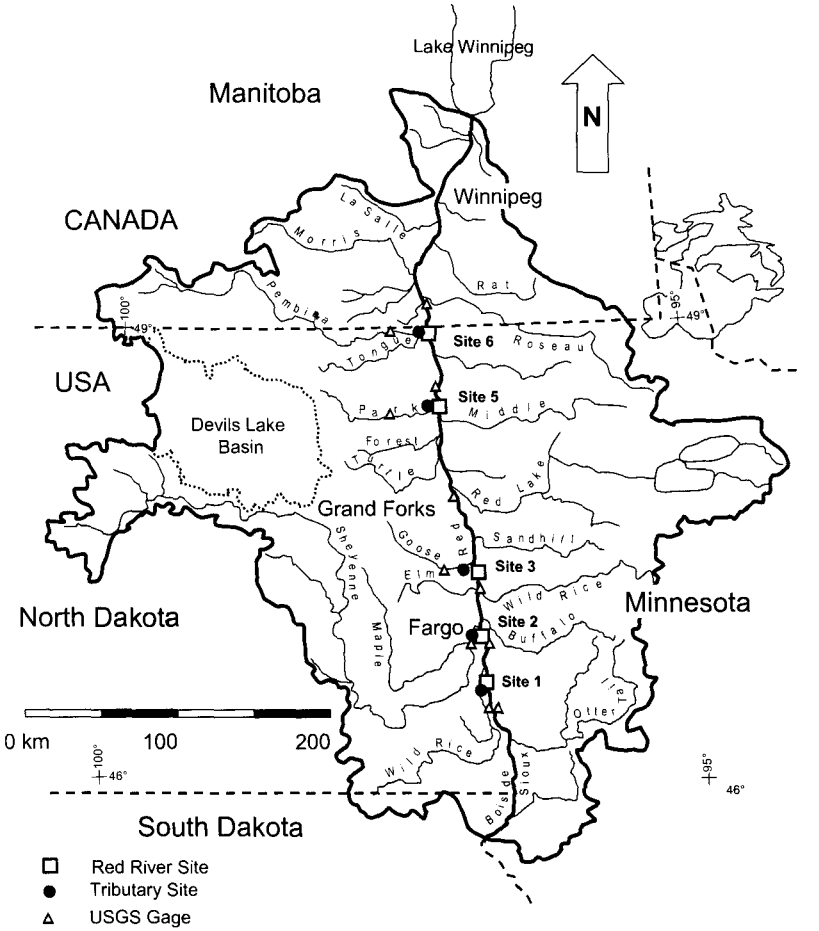

Figure 1. Map of study area displaying five pairs of sites sampled on the Red River North Dakota and associated tributaries.

floodplain that changes in elevation a mere 70 m along its 634 km course from origin to the Canadian border (Stoner et al. 1993). The watershed is altered by low-head dams, small reservoirs in tributary headwaters, and drainage ditches. Regular spring flooding from snow melt and rainfall and occasional summer flooding from widespread heavy precipitation are characteristic of the Red River. Floods often inundate the floodplain for days to weeks during the spring and summer.

METHODS and MATERIALS

All sampling was done in the silt-laden plain of the Red River valley ecoregion. Five pairs of sites were sampled during two years (1999 and 2000) of our study (Fig. 1). Sites on the Red River were located from 10 km south of Fargo, North Dakota (Red 1), north, to within approximately 2 km of the Canadian border (Red 6). Of each pair of sites, one was located on the tributary and the other on the mainstem Red River, both situated 0.5 to 6 km upstream from the confluence. Five of the largest tributaries to the Red River were sampled including the Wild Rice, Sheyenne, Goose, Park, and Pembina rivers.

Larval fish were collected with twin 0.5-m diameter plankton nets set side by side in a stainless steel bongo frame. Plankton nets had mesh size of 500 microns and a 5 to 1 ratio of length to mouth width. Each net had a detachable PVC collection container at the cod end. To estimate the volume of water filtered through each net, General Oceanic Flow Meters were suspended in the center of both net openings.

Samples were collected from 13 May 1999 through 31 July 1999 and from 17 April 2000 through 31 July 2000. Sites were sampled once a week. Nets were deployed from bridges by using a winch and boom assembly to ensure safe access during flood conditions. Plane shaped depressor weights with additional downrigger weights were attached to the steel cable to submerge the nets in the current.

Nets at Red River sites were set at different positions in the cross channel plane to accommodate spatial variability in the drift (i.e., mid-channel surface, near-shore surface, and mid-channel mid-depth). Nets were deployed only at the mid-channel surface position on tributaries. Nets were deployed for 15 to 60 minutes depending on the current velocity and amount of debris suspended in the water column. In situations when current velocity was inadequate to sample from a bridge, a small boat was used to tow the nets upstream from the regular bridge sampling station. The volume of water filtered by nets ranged from 100 to 250 cubic meters for all samples.

After each collection, nets were rinsed and contents transferred to Whirl-Pack sample bags. All samples were fixed in a five-percent buffered formalin solution in the field and placed on ice (Markle 1984). In the lab, samples were drained and washed under running water. Samples often contained large amounts

of detritus, zooplankton, and macro-invertebrates. Larval fish were separated from other material and identified by using a dissecting scope and several identification guides (Auer 1982, Fuimen et al. 1983, Holland-Bartels et al. 1990).

Discharge hydrographs were obtained from five United States Geological Survey (USGS) gages (Hickson, Fargo, Halstad, Drayton, and Emerson) on the Red River and the nearest USGS gage upstream on each of the five tributaries included in our study (Wild Rice at Abercrombie, Sheyenne at West Fargo, Goose at Hillsborro, Park at Grafton, and Pembina at Niche; Harkness et al. 2000 and 2001). Daily mean water temperatures were recorded at the USGS gages on the Red River near Fargo, North Dakota (Red 2) and Halstad Minnesota (Red 3) and on the Sheyenne River near West Fargo, North Dakota. All tributaries sampled had at least one USGS gage located on it. The surface current velocity was estimated by measuring the time it took for blocks of wood to travel a known distance.

We adapted a method developed by Nesler et al. (1988) to estimate spawn date (i.e., the date of oviposition and fertilization) for individual common carp larvae for use as an index of reproductive timing and spawning intensity. Spawn date was calculated on the basis of age determined from developmental stage and estimated incubation time. Common carp larvae were classified into eight developmental stages: 1, 2, 4, 7, 10, 15, 21 day, and 1 month based on a description of morphological characteristics, egg yolk absorption, and lengths (Verma 1970). Spawn date was calculated by using a method similar to Nesler et al. (1988) by subtracting age derived from Verma's age at developmental stage key and incubation time from capture date as follows:

$$Spawn = Capture - Age - (67/T_{C^\circ})$$

where Spawn = spawn date (Julian days), Capture = capture date (Julian days), Age = age at capture (days), 67 (degree-days) $\times T_{C^\circ}^{-1}$ = incubation time (days), 67 degree days = average of incubation times and temperatures taken from several sources (Swee and McCrimmon 1966, Verma 1970, Auer 1982), and T_{C°= daily average temperature over the incubation period. Incubation time was calculated by using a degree-day model where 67 degree-days are estimated for common carp eggs to hatch. The degree-day model was chosen to describe the relationship between egg incubation time and temperature because the model has been shown to provide similar precision to other more complex models (Hamel et al. 1997).

The spawn dates for 1999 and 2000 were compared by using a non-parametric Mann-Whitney U test. Correlations (Pearson Product Moment) were examined between discharge, and rate of change in discharge and Loge transformed larval carp numbers. A correlation also was performed between surface current velocity and the density of carp in the drift. At individual sites, spawn dates were compared graphically with the hydrograph and temperature regimes.

RESULTS and DISCUSSION

Eastern North Dakota received above average precipitation in 1999 and 2000, resulting in widespread flooding in the Red River Valley for periods during both years of our study. Flooding was present particularly along the section downstream from Grand Forks adjacent to the Forest and Park rivers. In 1999 peak discharge occurred in late April, which is typical of the northern plains climate due to spring snowmelt and rain. In atypical 2000 the region received little snowfall and spring precipitation, which produced low early-spring discharge. At times, several tributaries had no measurable current velocity. Peak discharge occurred later in 2000 following widespread precipitation that occurred in June. USGS gages marked a rise above flood stage at all our study sites north of Fargo, North Dakota. Water temperature regimes were similar at monitoring sites in 1999 and 2000.

In 1999 400 larval fish samples were collected and processed and 541 were collected and processed in 2000. Common carp, with 6,272 larvae caught, were the most abundant species collected. Common carp were captured in the drift later in the season in 2000 than in 1999 (Table 1). In 1999 the first common carp larvae were captured on 26 May and in 2000 the first larvae were captured on 13 June. The peak capture date occurred one month later in 2000 (26 June) than in 1999 (26 May). Common carp larvae might have been present in the drift after we ended sampling during both years, however, numbers dropped off substantially during the last two weeks of our study.

Seventy-seven percent of common carp larvae captured in plankton nets were classified as 1-, 2-, or 4-day-old larvae. Common carp in these classifications retain some of their yolk sack, a morphological feature that is identified easily. After the 4-day-old stage much of egg yolk sac has been absorbed (Verma 1970). With incubation times of 3 to 4 days, the spawn dates for the majority of captured individuals were estimated to be 4 to 8 days prior to the capture date.

Median spawn date for common carp was significantly different (Mann-Whitney U test; $Z = -53.808$, $p < 0.001$, $n = 6{,}080$) between 1999 (median = 31 May 2000) and 2000 (median = 22 June 2000) when it occurred 22 days later. In 1999, the duration of common carp spawning also was longer (15 May 1999 to 9 July 1999) than in 2000 (6 June 2000 to 9 July 2000). Spawning in 2000 most likely was constrained by lack of an early rise in discharge (Fig. 2).

Common carp in the Red River basin were found to spawn at similar temperatures reported in other studies. Temperatures recorded at USGS sensors (daily mean) on days when spawning was estimated to have occurred ranged from 15° C to 25° C during the two years of our study (Fig. 2). Optimal spawning temperature ranges have been reported to be 18 to 23° C (Auer 1982) and 19 to 23°

Table1. Number collected and capture dates for larval common carp collected in 0.5 m plankton nets (500 μm) in the Red River, North Dakota for 1999 and 2000.

Season	Number of carp larvae captured	Date of first carp larvae captured	Peak date of carp larvae capture	Date of last carp larvae captured
1999	2,130	26 May	27 May	30 July
2000	4,142	13 June	26 June	26 July

C (Swee and McCrimmon 1966). In 1999, carp spawning occurred as water temperatures approached 15° C. Peak (mode) spawning occurred on 29 May 1999 when USGS sensors recorded daily mean temperatures between 17.9 and 18.7° C. Temperatures had been increasing steadily during the prior days. In 2000, water temperature exceeded minimum reported spawning temperatures earlier in the season and rose above 20° C on 6 May 2000 but failed to trigger any successful spawning activity as indicated by the lack of larvae in the drift. After 15 May 2000, water temperatures remained within the 15 to 25° C range until the first week of July when 25° C was exceeded. Spawning in 2000 did not begin until 9 June when water temperatures ranged from 21.9 to 24.1° C. Peak (mode) spawning in 2000 was on 21 June; nearly seven weeks after the water temperatures exceeded the minimum threshold (15° C).

Peak common carp spawning appeared to coincide with discharge spikes at most sites during both years of the study (Fig. 3). Spawning activity did not coincide with peak discharge in 1999 at the Red 1 site. This might be due to the diminished accuracy of our method in back calculating spawn dates of the older larvae (i.e., stage category > 7-day old) of which these samples mostly were comprised. After the 2-day old stage in Verma's (1970) key, stages are identified at intervals of several days (e.g., 4-day old, 7-day old, 10-day old), which caused artificial gaps in the distribution of calculated spawn dates.

These results support our hypothesis that spawning is linked with discharge when water temperature is within a suitable range, suggesting that a discharge related environmental factor might be the cue triggering common carp to spawn. In 2000, common carp spawning coincided not with a minimum critical temperature but with increasing discharge after heavy rainfall in mid June ($r = 0.567$, $p = 0.001$, $n = 33$). The portion of watershed upstream from Fargo, south of the point where the Sheyenne and Buffalo rivers enter the Red River, did not receive the heavy summer rainfall like other parts of the watershed. The sampling station in this area (Red 1) did not receive the spike in discharge inundating the floodplain like other sites and as expected few common carp larvae were collected from this site.

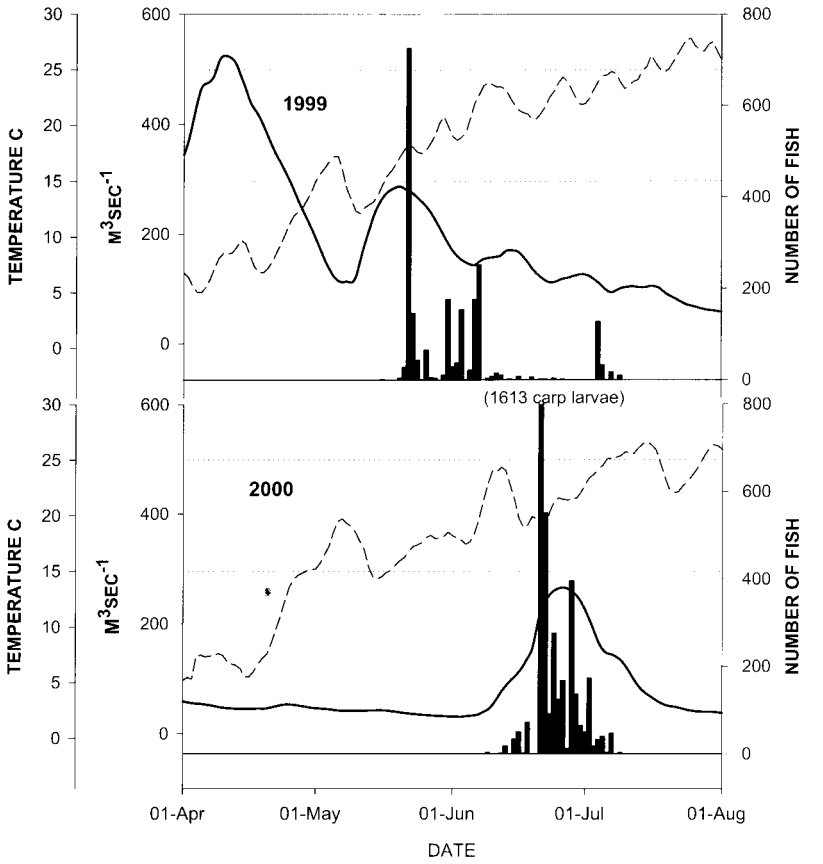

Figure 2. Calculated common carp spawn dates (bars), water temperature (dashed lines; average for all sites), and discharge rates (solid lines; average daily mean for all sites) for 1999 and 2000, The horizontal dotted lines represent the lower and upper bounds of the spawning temperature range reported in Auer (1982).

In 1999 discharge peaked in early April and river levels did not fall below flood stage until the end of May in much of the basin. Unlike the 2000 season, spawn dates in 1999 were not correlated significantly with increasing discharge ($r = 0.09$, $p = 0.598$, $n = 36$). During that year, common carp appeared to begin spawning as water levels were decreasing once temperature reached the lower end of their optimal range (18° C) in the third week of May. However, water levels were high in late May when temperatures rose to and remained above 18° C, the minimum temperature reported for optimal spawning (Auer 1982).

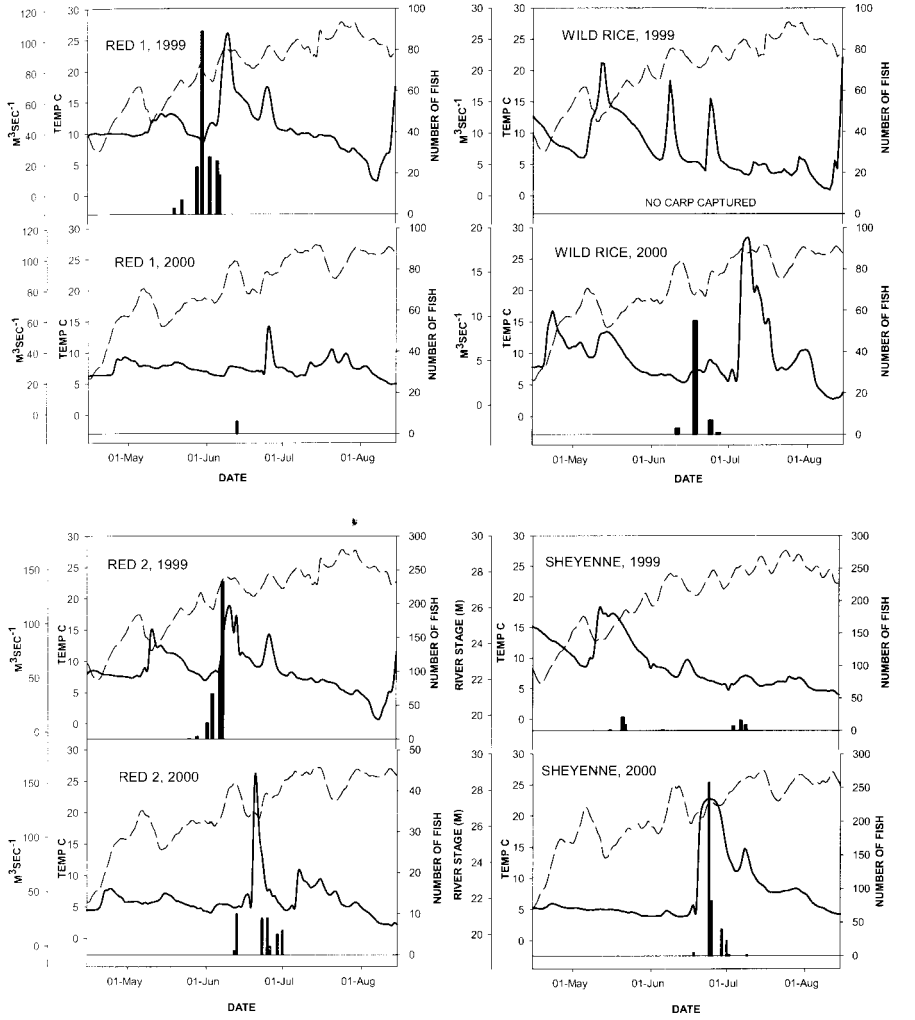

Figure 3. Calculated common carp spawn dates (vertical bars) with corresponding water temperature (dashed lines) and discharge rates (solid lines) for individual mainstem Red River and tributary sites in 1999 and 2000.

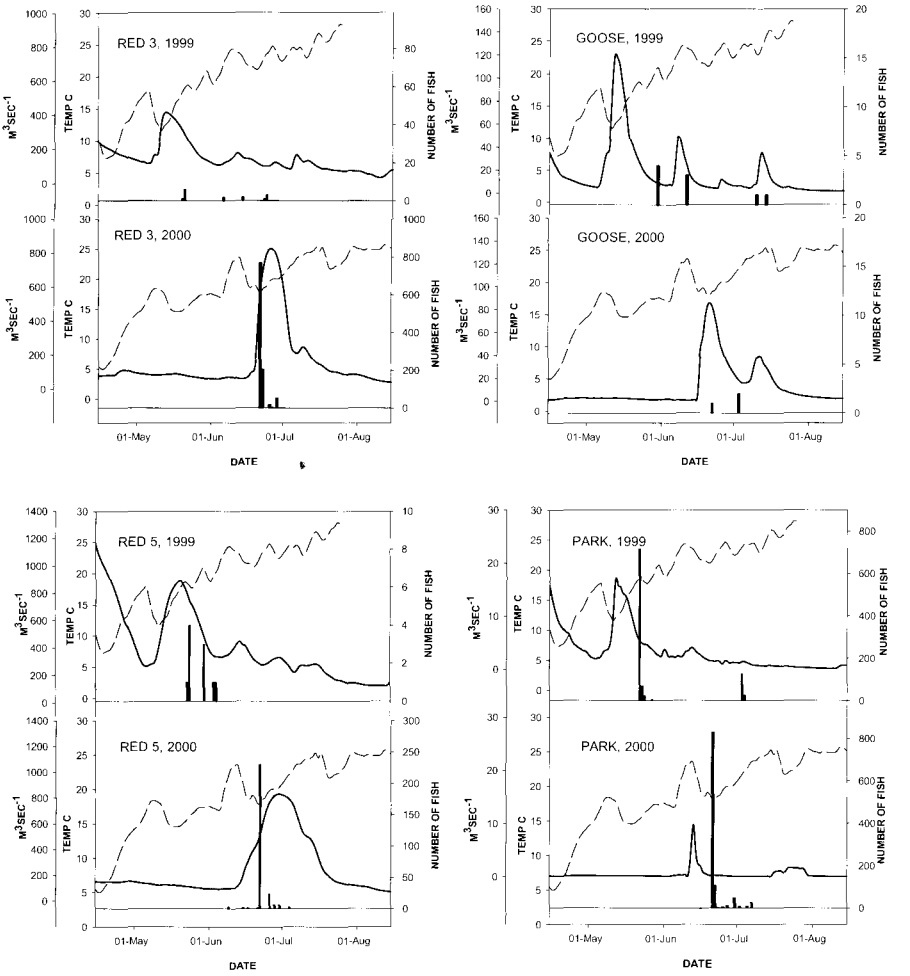

Figure 3, continued.

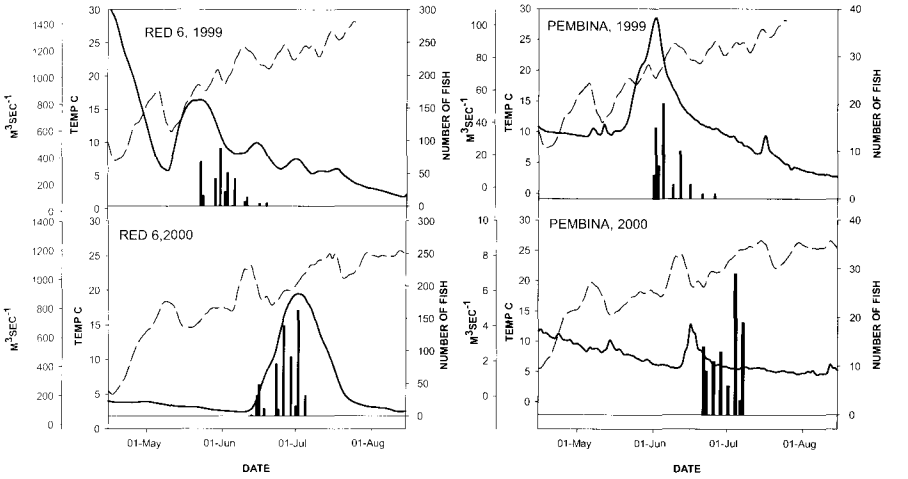

Figure 3, continued.

In 1999 when a large peak in spawning activity occurred early in the year, a smaller peak occurred at the beginning of July (Fig. 2). This peak might represent a second spawning event for common carp that spawned previously. Others have documented fractional spawning in this species (Swee and McCrimmon 1966, June 1977). A protracted spawning period, similar to what Phelps (2006) observed for common carp in South Dakota glacial lakes, also might explain this pattern. Our data indicated that successful spawning had ceased for the season by 10 July in both 1999 and 2000 because only larger individuals were captured during the last three weeks of sampling.

River discharge probably affected the susceptibility of carp larvae to capture by plankton nets. In addition to causing higher turbidity, high current velocity could displace larvae from flood plain and near-shore nursery habitat to the main channel where we targeted our sampling. Nesler et al. (1988) referred to this as a 'flushing effect'. So there was reason to consider the possibility that in 2000 common carp might have spawned earlier than our results suggested, but because of low discharge, might not have been sampled effectively until discharge began increasing mid June. We think this alternative explanation is unlikely for the following reasons. Current velocity was not correlated significantly with numbers of carp in the drift ($r = -0.048$, $p = 0.164$, $n = 857$), indicating that other factors also might influence the number of larvae moving downstream with river current. The age distribution through the course of the season also supported our argument. The date when the first common carp larvae appeared in samples at our ten study sites ranged from 13

June 2000 to 27 June 2000. All larvae captured during this period (n = 2,263) were 1-or 2-day-old larvae (with the exception of one 4-day-old individual), indicating that the spawning events that produced these individuals occurred 4 to 6 days before. The larger, older individuals were captured only during the following weeks, even after the peak in discharge subsided.

The numbers common carp larvae in light traps set overnight during the 2000 season at our tributary sites coincided with those of plankton net samples (Resseguie 2002). Common carp larvae were absent in light trap collections until 20 June 2000 similar to plankton net collections. The lack of carp larvae in light trap samples until their appearance in drift net samples further supported our argument that common carp were reluctant to spawn before the rise in discharge.

We have attempted to investigate factors that trigger common carp spawning activity by observing larvae in the Red River. Our findings suggested that both temperature and discharge might work simultaneously or in a hierarchy to cue ovulation and spawning in common carp in the Red River. Although we did not attempt to quantify available spawning habitat (submerged vegetation) or its relationship to discharge, we suspected that the presence of flooded terrestrial vegetation might be the factor that directly stimulated spawning in common carp in the turbid Red River, which lacked true aquatic vegetation. Spawning synchrony has been documented for the widely distributed common carp in many types of aquatic habitats (Swee and McCrimmon 1966, June 1977, Phelps 2006). Photoperiod, water temperature, wind/wave action, and discharge have all been identified as possible cues or controlling factors in carp reproductive timing. Understanding the complex hierarchy of environmental factors that influence reproduction in common carp will aid in the management and control of carp populations.

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NOTES

RAPTOR USE OF ARTIFICIAL PERCHES AT NATURAL AREAS, CITY OF FORT COLLINS, COLORADO -- The black-tailed prairie dog (*Cynomys ludovicianus*) remains a critical element of the prairie ecosystem even though its numbers and occupied range have declined dramatically since the arrival of Europeans in North America (Antolin et al. 2002). Prairie dog colonies are used by many species of wildlife and help maintain high levels of biodiversity (Kotliar et al. 1999). In the urban-suburban setting, the occurrence of prairie dog colonies also provides opportunities for wildlife viewing and environmental education. Unfortunately, prairie dogs also can come into conflict with humans, especially in the urban-suburban setting, where they cause vegetation and property damage, and pose a health threat attributable to periodic plague (*Yersinia pestis*) outbreaks (Witmer et al. 2003). Efforts to reduce conflicts can involve colony relocation or management so that the prairie dog population and occupied area does not increase (e.g., lethal or non-lethal removal, construction of physical barriers around the colony; Witmer et al. 2003). Artificial perches, placed at prairie dog colonies, can attract raptors, while providing for public viewing of raptors. The artificial perches, if strategically placed, also might increase predation on prairie dogs, slowing the increase in the size of the colony (Witmer et al. 2003). This approach has been used in other settings in an attempt to reduce rodent populations or damage, but most researchers reported little success in rodent control (e.g., Howard et al. 1985, Askham 1990, Moore and Van Vuren 1998, Wolff et al. 1999). A few researchers, however, reported that increased use of artificial perches might help reduce rodent numbers and damage (e.g., Kay et al. 1994, Mulner 2000, Hafidzi and Mohd 2003). In our region, this management practice might be especially effective given the paucity of trees (i.e., natural perches) in the shortgrass prairie outside riparian systems (Weaver et al. 1996). The objective of this study was to document the use of artificial perches by raptors and the food habits of these raptors within the city limits of Fort Collins, Colorado.

This study was conducted at three natural areas within the city limits of Fort Collins, Larimer County, Colorado. All artificial perches were on the natural areas properties. The Cathy Fromme Prairie Natural Area (CF), occupying about 437 ha, was located in southwestern Fort Collins. There were two artificial perches at CF. They were 204 m from each other and oriented along an east-west axis. The closest perch sites (trees or powerlines) were over 200 m from the artificial perches. About 2 km to the southeast of CF was Prairie Dog Meadow Natural Area (PD). This natural area, occupying about 34 ha, was located in south-central Fort Collins, and contained four artificial perches. These were oriented along a north-south axis. Starting with the northern most artifical perch, they were 55 m, 18 m, and 34 m apart. The closest perch

sites (trees or powerlines) were over 120 m from the artificial perches. About 1 km to the southeast of PD was Fossil Creek Wetlands Natural Area (FC). This natural area, occupying about 89 ha, was located in southeastern Fort Collins, and contained four artificial perches. Two were on the northern end of the natural area, were oriented along a north-south axis and were 90 m apart. The other two artificial perches were on the southern end, were oriented along an east-west axis, and were 10 m part. The closest perch sites (trees or powerlines) were over 100 m from the artificial perches. These natural areas were within the shortgrass prairie ecotype, but because they were in an urban-suburban setting, they contained many non-native species of plants. The region was characterized by hot, dry summers and mild winters where snow cover rarely persisted for more than a few days at a time. The region was semi-arid, receiving about 25 cm/yr of precipitation. The perches were made of natural tree trunks and branches. The height was 7-9 m and each had one (and occasionally two) cross piece 1 to 2 m wide.

Observations were made of the artificial perches during fall 1999 (27 October-12 December) and spring 2000 (21 March-9 May). We did not document raptor use of natural perches or powerlines. An observer, using binoculars, would sit quietly in a vehicle on a roadside within a few hundred meters of the artificial perches. Observation sessions were usually about 2 hr in duration. The presence and activity (perched, flying) of raptors were recorded. Miscellaneous comments also were made (e.g., large raptor chasing a smaller raptor). When a raptor was observed, the species was recorded when possible; however, observers were instructed to not risk disturbing the birds by leaving the vehicle or attempting to get closer to obtain a positive species identification.

A raptor food habits analysis was conducted by using regurgitated pellets found in the vicinity of the artificial perches. The pellets were collected at about two week intervals during fall of 1999 and spring of 2000. Because relatively few pellets were collected in the fall of 1999, an additional small collection was made during the fall of 2000. Each pellet was assigned a unique sample number. The pellets were not identified to raptor species and were pooled by season. Pellets were examined in the laboratory and samples of fur, feathers, scales, and toe-nails were removed and placed in a labeled sample bag. The remainder of the pellet was placed in a glass beaker to which a 0.8% solution of sodium hydroxide was added to dissolve all remaining material except bones (Green et al. 1986). The following day, the bone fragments were rinsed thoroughly in water and spread on absorbent paper to dry. Once dry, the bone material was added to the respective bag of materials saved earlier. The contents of each sample bag were examined under a dissecting microscope to determine the species of prey contained therein, by using a reference collection of identified fur, feathers, and bones (e.g., Witmer and DeCalesta 1986). The results were used to determine the frequency of occurrence of prey items in the fall and spring diet of raptors using the artificial perches.

There were 75 observation periods for a combined total of 128 hrs of

observation of the artificial perches during the fall of 1999 and the spring of 2000. Raptors were observed during 63% of the observation periods. During 51% of those periods, raptors were observed flying. During 62% of those periods, raptors were observed perched. The species observed were American kestrel (*Falco sparverius*), red-tailed hawk (*Buteo jamaicensis*), ferruginous hawk (*Buteo regalis*), bald eagle (*Haliaeetus leucocephalus*), and great-horned owl (*Bubo virginianus*). This list should not be considered inclusive because not all raptors could be positively identified to species given the no disturbance protocol. About 25% of the time we could not identify the raptor to species; this was generally when the raptor was flying at a distance away. Other raptors using grasslands as well as dryland and irrigated agricultural lands that have been reported in the general area include rough-legged hawk (*Buteo lagopus*), golden eagle (*Aquila chrysaetos*), northern harrier (*Circus cyaneus*), prairie falcon (*Falco mexicanus*), merlin (*Falco columbarius*), and burrowing owl (*Athene cunicularia*) (Stahlecker and Behlke 1974). There appeared to be little variation in raptor use of the areas during the two seasons, but the relatively small sample size precluded further analysis.

A total of 78 raptor regurgitated pellets was recovered from the vicinity of the artificial perches during fall 1999, spring 2000, and fall 2000. A wide variety of prey species was documented from the pellets, but the most commonly occurring were (in declining order of frequency) voles (*Microtus* spp.), prairie dogs, rabbits (*Sylvilagus* spp.), deer mice (*Peromyscus* spp.), and birds (usually not identified to species) (Table 1). Reptiles/amphibians (not identified to species) and insects (not identified to species) comprised a smaller, but notable part of the diet. Other mammalian species that occurred incidentally included chipmunk (*Tamias* spp.), eastern fox squirrel (*Sciurus niger*), shrew (*Sorex* spp.), an unidentified rodent, raccoon (*Procyon lotor*), and coyote (*Canis latrans*). The latter two species might have been fed upon as carrion. All of the major prey categories occurred in both the fall and the spring (Table 1). The occurrence of voles and reptiles/amphibians remained very consistent across seasons, while there were differences in the other categories. Rabbits, deer mice, and birds all increased in the spring diet, while prairie dogs and insects declined in the spring diet.

Black-tailed prairie dog is very susceptible to predation and a large number of predatory species, both avian and mammalian, will prey upon it (Hoogland 1995). Interestingly, black-tailed prairie dog might have evolved its colonial social behavior system, and its propensity to clip vegetation without eating much of it, in order to reduce predation pressure (Hoogland 1995). Compared to many rodent species, black-tailed prairie dog does not have a particularly high rate of increase; it is a seasonal breeder with females bearing only one litter of three young per year (Hoogland 1995). Feasibly, the raptor predation enhanced by the placement of artificial perches would help reduce colony expansion. Although the colonies we worked in had a history of expansion into bordering private lands, we did not attempt to document colony expansion in this study.

Table 1. Frequency of occurrence (%) of prey items identified in regurgitated raptor pellets (number of pellets in parentheses) collected in the vicinity of artificial perches on natural areas in the City of Fort Collins, Colorado, 1999 to 2000.

Prey Item	Fall 1999/2000 (29 pellets)	Spring 2000 (49 pellets)	Fall/Spring Total (78 pellets)
Vole	44.8 (13)	49.0 (24)	47.4 (37)
Prairie Dog	34.5 (10)	22.4 (11)	26.9 (21)
Rabbit	20.7 (6)	26.5 (13)	24.4 (19)
Deer Mouse	6.9 (2)	26.5 (13)	19.2 (15)
Bird	6.9 (2)	22.4 (11)	16.7 (13)
Insect	20.7 (6)	8.2 (4)	12.8 (10)
Reptile/amphibian	10.3 (3)	10.2 (5)	10.3 (8)

Manci (1992) and Gietzen et al. (1997) noted the value of large urban-suburban prairie dog colonies for large raptors along the Colorado Front Range. Our study documented that a variety of raptors will use artificial perches at urban-suburban black-tailed prairie dog colonies. It also demonstrated that a sizeable portion of the diet of those raptors will include prairie dogs. While this predatory pressure alone might not prevent the expansion of prairie dog colonies, it would probably slow expansion, thus helping reduce conflicts between humans and prairie dogs. Conversely, a declining acreage of occupied prairie dog colonies, as a result of development or plague outbreaks, might adversely affect raptor numbers in the region (Gietzen et al. 1997), ultimately reducing predation pressure on prairie dogs.

We would also caution, however, to not expect raptor predation alone to control colony expansion. There are numerous reasons for this, including the fact that prey populations generally drive predator populations, not the other way around (Erlinge and Hansson 1988). We also note the great-horned owl is nocturnal while prairie dogs are diurnal. Several of the raptor species that use prairie dog colonies (notably American kestrel and burrowing owl) feed primarily on insects and are too small to prey on prairie dog (e.g., Forren 1981). Also, some of the larger raptor species primarily might use artificial perches for resting rather than for actively hunting (Reinert 1984). Nonetheless, the placement of artificial perches and nest boxes could be considered a critical element of an integrated pest management program to reduce conflicts with rodent populations (Antkowiak and Hayes 2004).

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WEST NILE VIRUS ANTIBODIES IN BREEDING NORTH DAKOTA ICTERIDS -- Exotic infectious diseases can have devastating effects on the distribution and abundance of naïve wildlife species (Friend et al. 2001). West Nile Virus (WNV) is an exotic disease that was introduced into North America in 1999 and has resulted in the deaths of tens of thousands of birds (Marra et al. 2004). The natural cycle of WNV involves *Culex* spp. mosquitoes as principle vectors and birds as principle hosts, although humans, horses, and other mammals can become incidental hosts (Lanciotti et al. 2000). Because the virus can be fatal, outbreaks have become a national health concern for the human population, an economic concern for domestic animal losses, and a conservation concern for the status of free-living wildlife populations (Campbell et al. 2002). For birds, WNV infection can be lethal, but the degree to which birds are adversely affected varies among species and even between individuals within species (Komar et al. 2003).

In light of concerns regarding the status of North American bird populations, we captured adult, juvenile, and nestling icterids in central North Dakota and tested them for WNV-specific antibodies. Specifically, we wanted to determine if antibody positive blackbirds were present during the early summer breeding season prior to the peak of mosquito populations that typically occurs later in the summer. Sampling during the icterid breeding season also allowed us to test the hypothesis that nestling blackbirds are particularly vulnerable to the virus because they are confined to the nest, lack protective feathers, and have naïve immune systems. We also trapped mosquitoes to determine if *Culex tarsalis*, a known WNV vector in North Dakota (Bell et al. 2005), was present in our study area.

This study was conducted on 10 wetlands in Stutsman County, North Dakota, from 15 May to 16 July, in 2003 and 2004. A total of 170 free-ranging icterids (132 adults, 5 juvenile, and 33 nestlings) were captured and tested for WNV antibodies. We used a food-baited Troyer V-Top trap (JWB Marketing, West Columbia, South Carolina) to capture 56 blackbirds, including the following species: yellow-headed blackbird (*Xanthocephalus xanthocephalus*, n = 13), common grackle (*Quiscalus quiscula*, n = 38), red-winged blackbird (*Agelaius phoeniceus*, n = 3), and brown-headed cowbird (*Molothrus ater*, n = 2). A nest trap (Newbrey and Reed 2008) was used to capture 81 additional yellow-headed blackbird females and we obtained blood samples from 33 of their nestlings. Nestlings were between 8 and 11 days old and were sampled from a total of 27 nests. Additional blood samples were obtained from a road kill juvenile western meadowlark (*Sturnella neglecta*) and three house sparrow (*Passer domesticus*) individuals (an adult and two juveniles), but they were not included in estimates of WNV antibody-positive icterids.

A blood sample (< 150 µl) was collected via venous puncture at the brachial vein from all captured individuals. We banded yellow-headed blackbird individuals as part of a concurrent research project and clipped the outermost tail feathers of

all other individuals to prevent re-sampling. Whole blood was kept in heparinized microcapillary tubes on ice for no longer than 6 hours before it was centrifuged for 5 minutes at 7,000 RPM in a microcentrifuge. The serum portion was removed and stored at -20°C until lab analysis.

To determine if *C. tarsalis* mosquitoes were present at our study sites, we captured mosquitoes by using two carbon dioxide-baited traps (American Biophysics Corp., North Kingstown, Rhode Island). Mosquitoes were collected adjacent to two of our study wetlands from 9 June to 15 July, 2004. Traps were run for three consecutive 24-hour periods before mosquitoes were collected and promptly frozen at -20°C (Bell et al. 2005).

We tested avian serum samples for WNV antibodies by using competitive enzyme-linked immunoabsorbent assay (ELISA). The ELISA, using WNV-specific monoclonal antibodies, provides a non-lethal, rapid, and inexpensive technique for monitoring WNV infection in wild bird populations (Blitvich et al. 2003). We used serum from an infected horse and from normal chickens as positive and negative controls. A serum sample with inhibition >30% was considered positive for WNV antibodies (Blitvich et al. 2003). Approximately 25,000 mosquitoes were collected during the summer of 2004 and 291 female *C. tarsalis* individuals were recovered. Mosquitoes were tested for WNV RNA by using Reverse Transcriptase Polymerase Chain Reaction (Lanciotti et al. 2000) to determine if the primary WNV vector in North Dakota carried the virus during the icterid breeding season.

Of the 170 icterids sampled in 2003 and 2004, four individuals were positive for WNV antibodies (Table 1). In 2003, we tested serum from 53 birds and found one positive (1.9%): a male red-winged blackbird. In 2004, we tested serum from 117 blackbirds and found three positive (2.6%): two yellow-headed blackbird adult females and one adult common grackle. The juvenile western meadowlark collected in 2003 and two house sparrows (an adult and a juvenile) collected in 2004 also tested positive for WNV antibodies. All of the *C. tarsalis* mosquitoes sampled during the 2004 icterid breeding season tested negative for WNV RNA.

The occurrence of WNV antibodies in icterids in our study area was low during the early summer breeding seasons in 2003 and 2004, with 1.9 and 2.6% of blackbirds having antibodies, respectively. Our rates of antibody positive birds were slightly lower than those found in other free-living bird populations that have been monitored recently for WNV. Ringia et al. (2004) studied the prevalence of WNV antibodies in 81 species of North American birds in Illinois and found an overall rate of 5.3% (94 out of 1,784 tested) in 2002. Of 39 red-winged blackbird individuals sampled, three (7.7%) were found to be antibody positive (Ringia et al. 2004). Similarly, the North Dakota Department of Health tested 617 live birds for WNV antibodies during the summer of 2004, and found 36 positive individuals (5.8%, North Dakota Department of Health, unpublished data).

In our study we found birds with WNV antibodies despite the fact that none of the *C. tarsalis* individuals collected were infected with WNV. Possibly, adult

Table 1. Icterid species tested for West Nile Virus (WNV) antibodies in central North Dakota during the 2003 and 2004 icterid breeding seasons. The number tested and the number of WNV-antibody positive individuals are reported for each species.

	2003		2004	
Species	Tested	WNV Positive (%)	Tested	WNV Positive (%)
Yellow-headed blackbird	36	0 (0.0)	91	2 (2.2)
Common grackle	15	0 (0.0)	23	1 (4.3)
Red-winged blackbird	2	1 (50.0)	1	0 (0.0)
Brown-headed cowbird	-	-	2	0 (0.0)
Total	53	2 (1.9)	117	3 (2.6)

blackbirds were infected on their wintering grounds, but this seems unlikely. In our study, antibody positive birds were not detected until half-way through the breeding season (14 June), and one adult non-migratory house sparrow and two juvenile birds (a western meadowlark and a house sparrow) were also WNV-antibody positive, suggesting local infection. Another confounding factor could be the timing of our sampling; we sampled both birds and mosquitoes just prior to the peak of *C. tarsalis* mosquitoes. This might have contributed to the low number of birds and mosquitoes we detected with WNV.

Little is known about the influence of WNV on the reproductive success of North American bird populations. In this study, we sampled 33, 8 to 10 day-old yellow-headed blackbird nestlings, which were potentially at high risk of WNV exposure, but all were WNV-antibody negative. However, both of the WNV antibody-positive yellow-headed blackbird females experienced nest failure in 2004, suggesting potential impacts on population dynamics. Although this is anecdotal evidence, additional studies, including long-term monitoring of marked populations, are needed to help elucidate both the lethal and non-lethal impacts of WNV on North American bird populations.

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State University Institutional Animal Care and Use Committee (IACUC Protocol #A0326).—*Jennifer L. Newbrey[1,2] and Wendy L. Reed, Department of Biological Sciences, North Dakota State University, Fargo, ND 58105. [1]Corresponding author. [2]Current address: Department of Biological Sciences, University of Alberta, Edmonton, Alberta T6G 2E9, Canada. E-mail address: jennifer.newbrey@ualberta.ca*

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SEX-SPECIFIC FEEDING RATES AND PROVISIONING OF FRUIT TO NESTLING BELL'S VIREO -- Provisioning of fruit to nestlings and possible sex-specific differences in feeding rate have not been reported for Bell's vireo (*Vireo bellii*; Brown 1993). While studying nesting ecology of Bell's vireo on Konza Prairie Biological Station, Geary and Riley counties, Kansas, I quantified feeding rate by sex and food type delivered to nestlings. Sex was determined by capturing adults with mist-nets and inspecting for a cloacal protuberance, as well as conducting behavioral observations of uniquely-marked individuals. Males sing regularly while moving around territories, as well as during incubation (Nolan 1960). I assigned "female" to the individual in these socially monogamous pairs that did not sing or appear to regularly patrol territorial boundaries.

One-hour feeding samples were assigned randomly among five nests between 0600 and 1900 CST, preceded by a minimum 15-min interval. I used a 20-60x Bushnell spotting scope in blinds 15 to 25 m from nests to sample provisioning to nestlings between 24 June and 15 August 1986. Nests contained three or four Bell's vireo nestlings within one day of age of each other. At all but one nest, males made the majority of feedings between days one and seven post-hatch (mean 62%, range 33-83%; n = 36 visits). No differences were apparent in adult feeding rate by sex from eight days post-hatch until fledging at day 12 to 14, although a single nest received only female feedings the day of fledging (female mean 56%, range 42-100%; male mean 44%, range 0-58%; n = 36 visits). There were no detectable differences in prey size or type delivered by each sex.

I also noted rough-leaved dogwood (*Cornus drummondii*) fruit being fed to nestlings, as well as fruit consumption by adult Bell's vireo. These observations were made at a nest attended by two color-banded adults, located 1.1 m off the ground in a 2.5 m-high rough-leaved dogwood. All 40 nests monitored during this breeding season were in comparable microhabitats (Farley 1987). On 5 August, while brooding three 4-day old nestlings, the adult male expelled several rough-leaved dogwood stones into the nest. During a subsequent 35 min brooding interval by the adult female, she was fed three whole fruits by the attending male; 17 min later she expelled a single rough-leaved dogwood stone into the nest. The following day the same male twice regurgitated partially-digested fruits while brooding and attempted unsuccessfully to feed these to nestlings, only to swallow the fruits again. On 15 August the attending female fed regurgitated fruit to two nestlings; one nestling was observed to expel a rough-leaved dogwood stone 29 min later. Three 14-day old nestlings fledged later that day.

The regurgitated drupes did not possess the white exocarp diagnostic of ripe *C. drummondii* fruits; this waxy layer might have been digested partially by the adult prior to provisioning. I collected rough-leaved dogwood stones from within and below this nest to confirm plant species identification; the fleshy mesocarp was removed completely from each sample. Most North American vireos regularly

consume fruit as adults (e.g., Nolan and Wooldridge 1962, Williamson 1971, Rybczynski and Riker 1981), but Bell's vireo appears to be more strictly insectivorous, with less than 1% of plant material in its diet during the breeding season (Chapin 1925, Brown 1993). Barlow's (1962) exhaustive observations included only three instances of an adult consuming fruit, specifically a male consuming wild cherries (*Prunus* sp.) in September. I am unaware of records of fruit being delivered to nestling vireos. The extremely late date of the nest where these observations were made (median hatching date for all nests in 1986 was 9 July) coincided with the fruiting phenology of rough-leaved dogwood, possibly allowing use of a typically unavailable nestling food source. Alternatively, provisioning fruit to nestlings might only reflect typical adult dietary preference during this interval of their annual cycle.

My observations of adults feeding on rough-leaved dogwood fruits over a minimum 14-day interval late in the breeding season, as well as feeding nestlings fruit from 4-days post-hatch until fledging, suggested this food resource was likely available to immature and adult Bell's vireo until they left the breeding grounds. The nutritional composition of rough-leaved dogwood fruit might facilitate an increase in lipid stores prior to molt and migration. Skutch (1980) observed preferential foraging for oil-rich arils by Philadelphia vireo (*Vireo philadelphicus*) in Costa Rica prior to northward spring migration. In addition, frugivory might allow emancipation from the continuous foraging pattern typical of strict insectivores. When ripe fruits are abundant and readily accessible, individuals can fill their crops during a short foraging bout, freeing time for parental care duties.

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BREEDING BY THE SNOWY PLOVER IN NORTH DAKOTA AND SOUTH DAKOTA -- The snowy plover (*Charadrius alexandrinus*) is a small shorebird that breeds on unvegetated beaches along coastlines, rivers, and alkaline lakes. In North America, its breeding distribution extends along the coasts of California, Oregon, and southern Washington, where the population is listed as federally threatened (USFWS 1993), and an interior population occurs on wetlands in western and central states and central Mexico (Page et al. 1995). There have been rare breeding reports in Montana, Wyoming, and Saskatchewan (Page et al. 1995), but no documented breeding records in North Dakota or South Dakota. However, the United States Army Corps of Engineers reported a nest on the Nebraska side of Lewis and Clark Lake, a Missouri River reservoir between South Dakota and Nebraska in 1998 (Sharpe et al. 2001). We herein report the first records of snowy plover breeding in North Dakota and South Dakota.

Biologists have conducted annual surveys along the Missouri River and its reservoirs for the federally-threatened piping plover (*Charadrius melodus*) and the federally-endangered least tern (*Sternula antillarum*) from Nebraska to Montana since 1986. In addition, annual surveys for the piping plover have occurred on many alkaline lakes in central and northwestern North Dakota since the mid 1980's. Surveys are conducted at least weekly from mid-May through late-July in most locations. Therefore, we assumed that if the snowy plover was present in the Dakotas prior to 2007, it would have been detected with these intensive surveys. Indeed, in 2006, two fledged snowy plovers were observed at Long Lake National Wildlife Refuge (LLNWR), ND (ND Bird Listserv Record NDBRC No. 07-018), which were presumably from a nest in the area. In 2007, individuals of the snowy plover were observed on the sparsely vegetated shorelines at two alkaline lakes and four sandbars on the Missouri River system during surveys for the piping plover and the least tern.

At LLNWR, we documented four snowy plover nests during the 2007 nesting season on Long Lake (46° 43' N, 100° 06' W) (Carol Aron, Paul Van Ningen, Michael Rabenberg and Cheryl Jacobs, personal observation). There was at least one additional nest present that was not detected, because we observed an adult with two chicks while the four known nests were still being incubated. We observed five young from three different clutches. Two individuals fledged, likely from one of the three known successful clutches, although since the birds were not banded, we cannot be sure. Indeed, other snowy plover nests might have occurred, as only about 60 percent of the potential breeding habitat along Long Lake was surveyed. Snowy plover nesting also was documented at Stone Lake, a large alkali lake in central South Dakota (44° 52' N, 99° 45' W), with three chicks from three different clutches confirmed (Ricky D. Olson, personal observation). One chick near fledging age was observed with an adult. On the Missouri River in North Dakota, the snowy plover was observed at four locations in 2007, with nesting documented

at two of these; one on the Missouri River below Garrison Dam (47° 06' N, 100° 56' W) and one on Lake Oahe (46° 20' N, 100° 33' W). Eggs hatched in both of these nests, and the nest on Lake Oahe produced two fledglings (Greg Pavelka, personal observation).

In all cases, individuals of the snowy plover shared the same nesting beaches with individuals of the piping plover, and on the Missouri River, also with the least tern. We frequently observed the two plover species feeding together at all locations.

The appearance of the snowy plover in North Dakota and South Dakota coincided with spring flooding conditions on traditional breeding habitats in Texas, Kansas, and Colorado (Brad Andres, United States Fish and Wildlife Service, personal communication). The individuals of the snowy plover we observed might have been displaced and continued north to find suitable breeding habitat. The snowy plover is known to disperse great distances between nesting attempts (over 1100 km), thus long-distance dispersal is not unexpected in this species (Stenzel et al. 1994).--*Carol Aron[1], Paul Van Ningen, Michael Rabenberg, Cheryl Jacobs, Greg Pavelka, and Ricky D. Olson, U.S. Fish and Wildlife Service, 3425 Miriam Ave. Bismarck, ND 58501 (CA), U.S. Fish and Wildlife Service, Long Lake National Wildlife Refuge, 12000 353rd St. SE, Moffit, North Dakota 58560 (PVN, MR, CJ), U.S. Army Corps of Engineers, Lewis & Clark Lake Office, P.O. Box 710, Yankton, SD 57078 (GP), PO Box 622, Fort Pierre, SD 57532 (RDO). [1]Corresponding author. E-mail address: Carol_Aron@fws.gov*

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MORTALITY OF AN AMERICAN MARTEN FROM AN OFF-HIGHWAY VEHICLE -- Cause-specific mortality in American marten (*Martes americana*) populations has been documented throughout North America (e.g., Maine [Hodgman et al. 1994, Hodgeman et al. 1997], Ontario [Thompson 1994], Quebec [Potvin and Breton 1997], Oregon [Bull and Heater 2001], and British Columbia [Poole et al. 2004]). Studies of trapped and untrapped populations have typically implicated predation as the leading cause of natural mortality (Hodgman et al. 1994, Bull and Heater 2001, Poole et al. 2004). Coyote (*Canis latrans*; Bull and Heater 2001, Hodgman et al. 1994, Hodgman et al. 1997), raptors (Thompson 1994, Hodgman et al. 1997, Bull and Heater 2001), red fox (*Vulpes vulpes*; Thompson 1994, Hodgman et al. 1994), fisher (*Martes pennanti*; Hodgman et al. 1997), and bobcat (*Lynx rufus*; Bull and Heater 2001) have been identified as predators of American marten. Other known causes of natural mortality include intraspecific killing (Hodgman et al. 1994, Hodgman et al. 1997, Bull and Heater 2001), disease (Thompson 1994), and exposure (Bull and Heater 2001).

Studies of heavily exploited American marten populations have shown that trapping might account for up to 90% of American marten mortalities (Hodgman et al. 1994). Additionally, human-induced mortalities from trap-related injuries (i.e., traps targeting other furbearers; Potvin and Breton 1997), shootings (Potvin and Breton 1997), and on-road vehicles (Potvin and Breton 1997) have been documented. However, there have been no published reports of American marten killed from direct contact with Off-Highway Vehicles (OHV; i.e., all-terrain vehicles [ATV], off-road motorcycles or dirt bikes, snowmobiles, and four-wheel drive vehicles).

While there are several reviews of the effects of OHVs and recreational activity on wildlife populations (Knight and Gutzwiller 1995, Joslin and Youmans 1999), most studies have focused on physiological (Creel et al. 2002) or behavioral (Van Dyke et al. 1986, Riley et al. 2003) responses to disturbance; none have addressed the potential for direct mortality. In 2005, we documented the death from an OHV of a juvenile, female American marten (F299) that had been radiocollared during a study documenting the distribution and abundance of American marten in the Black Hills, South Dakota (Smith 2007); the Institutional Animal Care and Use Committee at South Dakota State University approved all handling protocols (Approval Number 04-A030).

We relocated F299 16 times between the date of capture (3 August 2005) and the date she was discovered dead. We located the carcass on 9 September 2005 in a dry creek bed in the Northeast region of the Black Hills, South Dakota, approximately 1-km south of the nearest secondary road. The base of the creek contained numerous large rocks making it impassable via ATV. A visual inspection of the carcass indicated severe rub marks and patches of hair missing on the head, shoulders, back, and front legs. The bottom third of the animal was beneath a small rock (approximately half the size of the American marten) and had

been compressed severely dorso-ventrally, suggesting that the American marten had been run over by a vehicle. An inspection of the head and upper torso showed no signs of puncture wounds or trauma typically associated with predation. Due to the nature of the wounds, the ruggedness of the terrain, and the fact that we were unable to gain access to the creek bed via ATV, we concluded that the animal was crushed by a large OHV. We noted potential den site locations within 2 meters of the death site. Based on the physical evidence at the death site, we are certain the animal was not killed by being directly under the rock. Although the exact circumstances leading to the mortality are unknown, possibly the animal was denned in the creek and consequently struck and killed while attempting to escape the approaching OHV. The general area where the carcass was discovered is a popular destination for off-road enthusiasts, and during the course of our study, we routinely witnessed OHV traffic in adjacent areas.

While probably not a significant source of mortality in American marten populations, the potential for injury or death from OHV contact does exist. With an estimated 11 million visits to national forests nationwide (USDA Forest Service 2003), use of OHVs for recreational purposes is one of the fastest growing activities in the United States (Cordell et al. 2005). Thus, we think OHV use should be considered when addressing long-term viability of American marten populations, especially in sensitive areas, such as the Black Hills of South Dakota and Wyoming.

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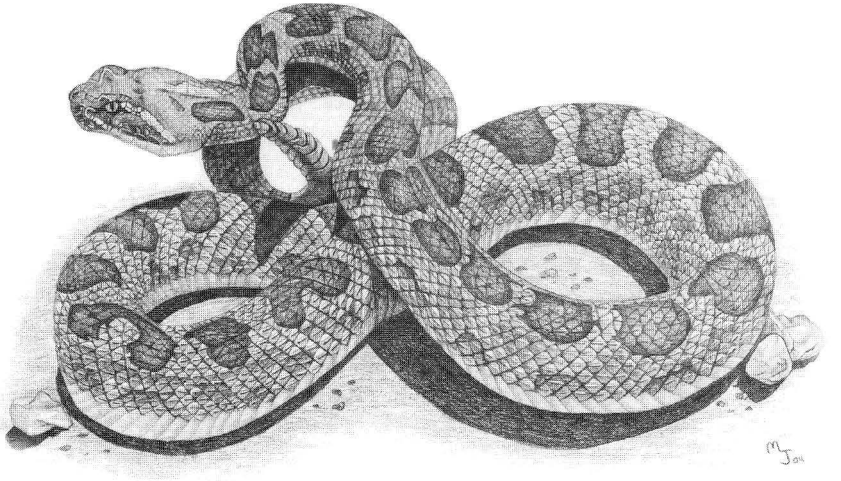

Book Reviews

ROGER TORY PETERSON: THE MAN THROUGH HIS WORK

Roger Tory Peterson: A Biography. Douglas Carlson. 2007. University of Texas Press, Austin, TX. 296 pages. $24.95 (hardcover).

August 28, 2008, marks the centennial of Roger Tory Peterson's birth, and books related to the most prominent naturalist of the twentieth century have been sprouting up everywhere. I was disappointed that Douglas Carlson shied away from examining Peterson's personal life to provide insights into the forces and relationships that shaped, and were shaped by, this man so consumed with birds. Instead, Carlson focuses almost entirely on Peterson's work, writing, "Because his death is so recent, there are many who have a personal investment in his story; beyond a request for an interview, no attempts have been made to invade the privacy of any of them. Through Peterson's painting and writing, and in the work of the Roger Tory Peterson Institute, the truths of his life are revealed."

The book might more appropriately have been titled Roger Tory Peterson: The Man through His Work, and within this context Carlson does an admirable job, examining in great detail specific examples of both Peterson's writing and his artwork, and tracing Peterson's evolution from artist, educator, and naturalist to activist. Carlson notes with regard to the fight to ban DDT that Peterson wrote to a friend in 1962, "We have got to be far more militant, and I am afraid that biologists as a whole have got to be a bit more aggressive from now on." In April 1964, the month Rachel Carson died, Peterson testified before a subcommittee of the U.S. Senate Committee on Government Operations, recommending that "Aldrin, endrin, dieldrin and all compounds of the chlorinated hydrocarbon complex be banned. Permits to manufacture them should be withdrawn." In the intervening years until DDT was banned in 1972, Peterson waged a tireless campaign to educate the public and government officials about the issue, and for years afterward continued to collect data about the long-term effect of the ban on his beloved local ospreys.

Carlson writes that Peterson "never set out to become the most significant naturalist of his time," but the details of his life belie that. After the full-color Golden field guide by Chandler Robbins and others was published in 1966 to wide praise, Peterson set to work on all-new Eastern and Western editions of his guide in full color. When a new generation of sophisticated birders wrote less-than-glowing reviews of this new guide, Peterson literally went back to the drawing board and started laboring on yet another edition-a depleting and ultimately thankless task that consumed him, preventing him from finishing other more enjoyable and, perhaps, more important writing, artistic, and conservation projects.

This fifth and final edition of his field guide was not quite finished at his death in 1996, and was published posthumously.

Despite his competitiveness and an ego to match his abilities, Peterson was generous with his knowledge and time, as I can personally attest-he wrote a detailed response to a question I sent him back in the late 1980's, when he was being bombarded from all sides with such trivial, as well as far more important, requests. Douglas Carlson's close examination of his huge body of written, photographic, and artistic work makes the book a worthwhile entry in the library of books about this interesting man who sparked a widespread and enduring interest in birds and nature study.—*Laura Erickson, Ithaca, NY 14850.*

EGGS WITH STORIES TO TELL

Oology and Ralph's Talking Eggs. Carrol L. Henderson. 2007. University of Texas Press. Austin, TX. 177 pages. $29.95 (hardback).

Ralph Handsaker was an Iowan farmer whose "ravenous curiosity" (page 4) about the natural world inspired him to become an oologist, or egg collector. This book tells the story of Handsaker's eggs, contained in two large cabinets that remained hidden in the living room of his boarded-up house after his death in 1969, until they were rediscovered in 2003 and shown to the author, wildlife conservationist, and photographer, Carrol Henderson. Ralph's eggs can "talk" by virtue of Henderson's chronicle-using the eggs as guides-of not only Ralph's own passion for natural history and egg collecting, but also the history of conservation and the network of fellow oologists from whom Ralph obtained many eggs from all over the world.

After a chapter that provides the background for the rediscovery of the Handsaker eggs, chapters briefly describe the early history of oology (including accounts from the field and descriptions of equipment, trading networks, books, bird trading cards, and journals), note extinct birds whose demise oologists may or may not have been partly responsible for, and explain how eggs are classified by size, shape, color, and marking. The heart of the book, however, is Chapter 6, in which the author uses Handsaker eggs from 60 different species, accompanied by beautiful photographs, to tell pithy stories about the birds themselves, relate anecdotes about collecting, and explain the birds' current conservation status. These stories are interspersed with highlights in the history of conservation, correlated to the year in which Ralph collected the eggs of the bird being described.

Henderson points out that, because the eggs can no longer be legally sold or traded, "the real value of the Handsaker collection is in the scientific information contained with the eggs" (pages 6-7). Henderson's account as a whole also demonstrates an additional merit in the collection's nostalgic value. "Each time I sat down with the collection," he writes, "the egg cabinets became time machines that transported me back to the era in which the eggs were collected" (page 8). This is not a book that tries to explain the changing cultural context of oology or provide the intellectual or cultural context for the rise of conservation, and certainly it never satisfactorily addresses the tension between egg collecting and conservation. But with its photographs, the accounts of egg collectors in the past, and conversational tone, this book helps transports its readers, too, to a bygone era.—*Kristin R. Johnson, Science, Technology and Society Program, University of Puget Sound, Tacoma, WA 98416.*

A TEXAS BIRD HANDBOOK

Basic Texas Birds: A Field Guide. Mark W. Lockwood. 2007. University of Texas Press, Austin, Texas. 403 pages. $22.95 (paper).

Texas has an incredible diversity of birds. This diversity is a result of its geographic location, size, and diversity of habitats. Given this wealth of birds, there is a wonderful opportunity in Texas for both residents and visitors alike to learn and appreciate the birdlife found there.

Basic Texas Birds has been written to provide a foundation for anyone who is either new to bird-watching or has been bird-watching casually for several years. The book covers 161 commonly occurring birds in Texas and includes an additional 23 species that are considered Texas specialty birds, those that occur regularly in Texas but nowhere else in the United States.

This book is filled with beautiful pictures, clear and accurate range maps, and an abundance of interesting natural history information in an easy-to-handle small form. Each species gets two pages worth of coverage, which includes the species' background, identification, similar species, habitat, status, and distribution.

Unfortunately, I believe the book has several shortcomings. The first and foremost is a matter of semantics as it relates to the subtitle. It is subtitled as "A Field Guide," yet its format is not effective for identifying birds in the field. Perhaps a more appropriate subtitle would be A Natural History Handbook. The term "field guide" implies a book that can be used in the field to identify some particular subject. Even the author, whom I respect greatly, candidly mentions in the section "How to use this book" that a more-inclusive guide will be needed when observing birds. Unfortunately this ignores the basic human behavior of not reading the fine print and blazing to the main text or illustrations and thus potentially bolstering unrealistic expectations.

There are several species accounts that either do not illustrate both a male and female or include a picture that does not adequately accentuate the best identifiable characteristics. There seemed to be a strong interest in including pictures that were aesthetically pleasing or illustrating some unique behavioral perspective. This is quite appropriate for a natural history book, but a shortcoming for a field guide.

Two species accounts contain minor errors. The first deals with the brown-headed cowbird (*Molothrus ater*). The map for the bronzed cowbird (*M. aeneus*) was repeated in the brown-headed cowbird account. The second error is subjective on my part, but one I feel is important. That is the reference of the crested caracara (*Caracara cheriway*) as the Mexican eagle. I and others believe that the crested caracara is not the true national bird of Mexico. The crested caracara/Mexican eagle issue is an unfortunate one that is often repeated by many authors out of convenience and not, in my opinion, based on a true evaluation of the Mexican coat of arms and flag as well as the legend where it was born.

I also found the index very confusing with some dead-end leads and difficulty in locating the treatment of a particular species. I believe the author, in an attempt to fill in the gap of species not covered by the book, added many species in the "similar species" category and thus made for a congested and deceptive index.

If this book is purchased with the hopes of being used as an actual field guide, the reader may well be disappointed and frustrated. The 184 bird species that Basic Texas Birds specifically covers pale in light of the 600+ species that have been recorded in the state. When this book first appeared on the shelves of a local bookstore, I initially was excited at its title, the author, and the thoughts of a good field guide focusing specifically on Texas birds, something that is really lacking. My initial perusal quickly made me realize that it had some of the same limitations of other recently published Texas "bird field guides": a limited number of species illustrated and an inefficient field guide format, typically with one species illustrated per page. Unlike other Texas field guides, the range maps in Basic Texas Birds are some of the best I have seen. An appendix includes the entire list of birds documented in Texas as of December 2006.

I cannot recommend this book as a primary guide for bird identification. But outside of that issue, it does provide good natural history coverage of each species in a consistent and thorough manner within the space available. If it is used as a convenient supplement to a more standard field guide in dealing with the birds of Texas, your disappointment will be limited only to the species not covered by the book.—*Thomas M. Langschied, Caesar Kleberg Wildlife Research Institute, Texas A&M University-Kingsville, Kingsville, TX 78363.*

SUGGESTIONS FOR CONTRIBUTORS

The Prairie Naturalist is devoted to research on the North American Great Plains and its biota. Manuscripts containing original material will be considered without regard to individual membership in the Great Plains Natural Science Society. Manuscripts submitted should not be currently under consideration for publication elsewhere.

Electronic submission of manuscripts, by e-mail attachment, is preferred. Manuscripts and correspondence regarding manuscripts should be sent to Dr. Christopher Jacques, Editor, *The Prairie Naturalist*, Wisconsin Department of Natural Resources, 2801 Progress Road, Madison, WI 53716. E-mail address: Christopher.Jacques@wisconsin.gov. Telephone: (608) 221-6358, FAX: (608) 221-6353. Manuscripts will be forwarded to the appropriate associate editor for the subject area. Allow three to four months for manuscript review and evaluation. Book reviews and books for review should be sent to Douglas H. Johnson, Book Review Editor, Department of Fisheries, Wildlife, and Conservation Biology, 204 Hodson Hall, University of Minnesota, St. Paul, MN 55108. Telephone: (612) 624-4716.

Style. Authors should follow a clear and concise style. Use active voice whenever possible. Use past tense verbs for Study Area and Results sections. The CBE Style Manual (5th edition or later) is a good reference for manuscript preparation and general rules of style. However, for the Literature Cited section, we prefer the style given at http://www.fhsu.edu/biology/pn/prairienat.htm

Preparation. Manuscripts should be single sided, with pages numbered, double spaced throughout, and have a one-inch margin all around. Do not include any headers or footers. Lines should be numbered. Longer papers may have sections, with headings such as Study Area, Methods, Results, and Discussion. Electronic submission of manuscripts is preferred, but hard copy submission is also acceptable. In the case of hard copy, four copies are required for review purposes. Manuscripts of more than two pages and containing figures and/or tables will generally be reviewed as Articles. All Articles must contain an abstract and an alphabetized key word list. Manuscripts of two or fewer pages and lacking tables and figures will be reviewed as Notes. Notes should not contain sections, and the author's name(s) and address(es) should be at the end of the note, not at the beginning as in Articles. All other style rules for Articles apply to Notes. After acceptance for publication, the final manuscript, in Word format, should be submitted to the associate editor by e-mail attachment. At the associate editor's discretion, one hard copy may also be required.

Figures. Electronically created figures (graphs, maps, digital photos, etc.) are preferred. Hard copy figures, such as high-quality illustrations, also may be submitted. These should be identified on the back with author's name, figure number, and an indication of the top of the figure. Figures should be referenced sequentially in the text, and should be sharp and clear. Scale should be indicated. Letters and symbols must be large enough to be clearly legible after reduction. *The Prairie Naturalist* publishes in black and gray only. Captions should be included on a separate sheet at the end of the manuscript.

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References. Manuscripts cited in the text of Articles and Notes should be indicated in parentheses by author's last name and year of publication: (Wade 1967). When a citation has more than two authors, the name of the first author followed by et al. should be used. Where two or more papers by the same author(s) have appeared in one year, the style should be: (Stewart 1967a, 1967b). References cited in the text of Articles and Notes should be listed at the end of the manuscript in a Literature Cited section. Journal titles should not be abbreviated. In a listing for a book, the title is not underlined, and the number of pages is not included. See a recent issue of *The Prairie Naturalist* or the Style Rules section on our above listed web page for specific examples.

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EDITORIAL POLICY

1. Manuscripts on any aspect of the biology of the North American Great Plains and the organisms living in this region will be considered for publication. Studies on grassland habitats in areas outside this region will also be considered.
2. Manuscripts must be based upon information that has not been published elsewhere and must not have been simultaneously submitted to any other journal.
3. The Editor or Assistant Editor will acknowledge receipt of the manuscript.
4. Each manuscript will be forwarded to the appropriate Associate Editor, who will send it on to two individuals for review. The reviewers will be specialists in the subject of the manuscript and will be selected by the Associate Editor.
5. A pool of potential reviewers is maintained by the Associate Editors and the Editor. This pool consists of individuals who have previously reviewed articles for *The Prairie Naturalist* and others who volunteer to serve and who indicate appropriate areas of expertise.
6. Reviewers will be expected to evaluate the manuscript on the basis of scientific accuracy, readability, and suitability for *The Prairie Naturalist.*
7. Reviews will be prepared on a page that may be transmitted to the author(s). Additional comments may be written on the copy of the manuscript. Reviews may be signed or anonymous. If the latter, the review must be transmitted with a signed cover letter.
8. Reviewers will be asked to complete the review in two weeks or to return the manuscript to the Associate Editor.
9. If the review process requires more than six months, the Associate Editor will notify the author(s) of the reasons for the delay and the anticipated notification date.
10. If the two reviews are contradictory, the Associate Editor will submit the manuscript to a third reviewer.
11. The Associate Editor will inform the corresponding author of the acceptability of the manuscript within a reasonable time (typically less than three months from date of manuscript submission).
12. Manuscripts returned to authors for revision must be retyped following the style rules of *The Prairie Naturalist.* Manuscripts requiring major revision may also be subjected to further review.
13. The Associate Editor will notify the corresponding author that they have a limited time, usually five weeks, in which to complete any requested manuscript revisions. Manuscripts returned later than the acceptable time may be treated as new manuscripts and re-subjected to the review process. If the corresponding author needs additional time to complete revisions, he or she should contact the Associate Editor to request more time.
14. Once revisions are completed, the final version of the manuscript should be submitted to the Associate Editor, as an e-mail attachment in Word format. One hard copy of the manuscript may also be required at the discretion of the Associate Editor.
15. A pdf copy of the galley proof will be sent to the corresponding author. A hard copy or electronic copy of the manuscript, marked with corrections, is to be returned to the Assistant Editor within three business days of receipt. Notification will also be sent at this time regarding the issue in which the manuscript will be published, the probable number of pages, and the estimated publication charges.
16. Printer's errors will be corrected at no additional charge. Added content and extensive corrections by the author may be billed to the authors at a specified rate.
17. Following final acceptance by the Editor, manuscripts will be published in the next issue in which space is available.
18. The Editor will prepare an annual report for presentation at the annual meeting of the Great Plains Natural Science Society in August. The report will include the number of pages published, and the extent to which page charges were assessed.
19. Suggestions for contributors will be published annually in the March issue.

THE COVER AND ITS ARTIST

The range of the black-footed ferret (*Mustela nigripes*) once extended across twelve U.S. states, two Canadian provinces and northern parts of Mexico. Due to loss of grassland habitat, eradication programs for prairie dogs (its chief food source), and sylvatic plague, the black-footed ferret is now found on only 2% of its native range. As recently as 1979 it was considered to be extinct, and is still one of the most endangered mammals in North America.

In 1981 a small population of about 130 ferrets was discovered in Wyoming. A captive breeding and reintroduction program was initiated. Reintroduction sites in Wyoming, Montana, South Dakota, Colorado, Utah, Arizona, New Mexico, and Kansas could help reestablish this mammal in its former range.

Scott Caspers is currently a student in the Biology program at Fort Hays State University. Art makes up a large part of his background and has always been a passion of his, along with the natural world and all its wildlife. His interests include conservation and preservation of nature for generations to come. Scott plans to obtain a degree in either Zoology or Wildlife Management, and then attend Veterinary School in the future. Featured on the cover are two black-footed ferrets drawn in graphite.

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Annual membership dues are $10.00 for students, $15.00 for individuals, $20.00 for families, $30.00 for libraries, and $40.00 for patrons. Life memberships are available for $250.00, payable in 1 to 3 annual installments. Addresses outside of the United States are charged an additional $5.00 for postage. All prices are in United States funds. All memberships include subscriptions to *The Prairie Naturalist* and the Great Plains Natural Science Society Newsletter. Correspondence concerning memberships should be directed to Hilary Gillock, Assistant Editor, at the address below.

Manuscript submissions and correspondence should be directed to Christopher N. Jacques, Editor, *The Prairie Naturalist*, Wisconsin Department of Natural Resources, 2801 Progress Road, Madison, WI 53716. E-mail address: Christopher.Jacques@Wisconsin.gov. More detailed instructions for authors can be found on *The Prairie Naturalist* web site at: http://www.fhsu.edu/biology/pn/prairienat.htm.

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